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Vol. 13, No. 1

FT food technology

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THE JOURNAL OF THE INSTITUTE OF FOOD TECHNOLOGISTS

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IN THIS ISSUE—

THE TECHNICAL ARTICLES IN BRIEF

Chemistry *Starch*

Starch chemistry for the food technologist. L. M. Waldt and D. Kehoe.

A short review of starch chemistry is herein presented, particularly as it affects the food technologist and the food processor. With special emphasis on viscograph charts, an attempt has been made to elucidate and explain the behavior of cereal and root starches under the varying conditions of food manufacture. Viscosity and gel characteristics of the starches are then discussed and it is pointed out wherein these characteristics can be modified by the starch chemist to meet the demands of the food processor. The newer ideas of starch chemistry from a polymeric point of view are also discussed and what these modern ideas mean to the food technologist in developing new food products and food processes. (See page 1.)

Quality control *Analysis of soluble solids content*

Relationship of naturally occurring tartaric acid to certain physical constants of concentrated Concord grape juice. John B. Wegener.

Regression curves relating soluble solids, as sucrose, determined refractometrically to per cent by weight of tartaric and malic acid have been developed. These relationships are a new contribution. A regression curve relating soluble solids, as sucrose, determined by the Brix hydrometer, to per cent by weight of tartaric acid has also been developed. When the soluble solids of a tartaric acid sugar solution are evaluated by the refractometer, a positive correction is required. The amount increases with increasing tartaric acid concentrations. A negative correction value must be applied when the soluble solids are obtained by the Brix hydrometer. The degree of correction also increases with increasing tartaric acid concentration. When the corrections are applied, both methods of evaluating total soluble solids of synthetic mixtures of tartaric acid and sucrose yield values agreeing very closely with the amounts present. When the methods are applied to grape juice concentrate, the values obtained by the refractometer are much closer in agreement with the solids obtained by the official oven-drying procedure than are the Brix values. The average variation of soluble solid content of grape concentrate determined by the Brix method from values obtained by the official drying method are five times the corresponding average variation given by the refractometer. (See page 4.)

Physical measurement *Viscosity of citrus concentrates*

Viscosity of frozen concentrated orange and grapefruit juices. George H. Ezell.

Viscosity of both commercial and experimental samples of frozen concentrated orange juices was measured to determine if any relationship existed between viscosity and quality. Concentrated orange juices have thixotropic properties due chiefly to the presence of pectic substances. Procedures for the determination of the viscosity of these non-Newtonian products are described; both the Brookfield Viscometer and a standardized pipette were used. Data are presented showing the viscosities of (a) commercial samples of frozen concentrated orange juices collected from Florida plants during the 1956–57 citrus season, (b) experimental samples produced using various processing procedures, (c) samples of orange concentrate withdrawn from evaporators at various stages of concentration, and (d) products produced from freeze-damaged fruit. The relationship between viscosity and characteristics of concentrated orange juices, such as pulp content and degree of gelation or clarification are discussed. (See page 9.)

Frozen foods technology *Estimating changes in quality*

Time-temperature tolerance of frozen foods. XV. Method of using temperature histories to estimate changes in frozen food quality. W. B. Van Arsdel and D. G. Guadagni.

A procedure for the estimation of the accumulated change in a product which has experienced an irregular but known temperature history is described. The procedure involves determining the area beneath the corresponding irregular time-temperature curve plotted on a transformed coordinate system derived from, and depending on, the observed relation between relative rate of change and temperature. The area beneath the curve is proportional to the total amount of change in the measured quantity. This is equivalent to an integration (by graphical means) over the temperature history. Using this procedure, good agreement was obtained between calculated and actual experimental values of color and ascorbic acid changes at various points in an irregular time-temperature pattern. This is in agreement with results from regularly fluctuating temperatures and shows that temperature variation has no special effect. It is shown, therefore, that the quality loss or remaining "high quality life" of a product can be estimated from its temperature experience even though it is irregular, provided it is known. (See page 14.)

January Cover. The January cover, courtesy of the American Can Co., shows scientists at work with a Votator heat exchanger in connection with the development of aseptic canning. In aseptic canning food and cans are sterilized before the cans are sealed.

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Poultry tenderness *Turkeys*

Poultry tenderness. I. Influence of processing on tenderness of turkeys. A. A. Klose, M. F. Pool, M. B. Wiele, H. L. Hanson, and Hans Lineweaver.

Tenderness of turkey fryers and some turkey roasters was studied as a function of conditions of scalding, feather picking, and holding (aging) at various temperatures before, during, and after frozen storage. Shear force values were found to be relatively good indices of toughness as subjectively expressed by the ranking of a trained taste panel. Tenderness of turkey fryers increased progressively with increase in aging (chilling) time up to at least 12 hours. Changes were rapid and highly variable within the first 4 hours. Little if any additional tenderization took place from 12 hours to 24 hours post mortem, and even to a total aging time of 4 or 5 days. Turkey roasters appeared to be adequately tenderized after only 4 hours of chilling. For the same size and age of turkey, deep fat frying resulted in much tougher meat than roasting. Holding inadequately aged, frozen turkey fryers for as long as 9 months at 0° F. had no tenderizing effect, but holding at 25–27° F. for 1 to 2 weeks produced appreciable tenderization. Holding fryers in a thawed (35° F.) state after frozen storage had essentially as much tenderizing effect as an equal period of chilling before freezing. An elevation of the holding temperature to as much as 100° F. for 4 hours did not produce adequate tenderization. Either increased scalding temperature or increased scalding time, within commercial ranges, had significant but small toughening effects. Machine picking as employed in these studies resulted in cooked meat about twice as tough as for hand-picked controls. Toughening effects of individual picking machines on a commercial line of machines were accumulative. Differences in shear values between machine-picked and hand-picked birds were essentially unaltered by extended chilling periods. At present, optimum tenderness can be assured only through careful attention to chilling (aging) periods, feather picking conditions, and scalding practices. (See page 20.)

Poultry tenderness *Chickens*

Poultry tenderness. II. Influence of processing on tenderness of chickens. M. F. Pool, D. de Fremery, A. A. Campbell, and A. A. Klose.

Tenderness of chicken fryers was studied as related to conditions of scalding, feather picking, chilling or aging, and frozen storage. Effects reported for turkey fryers were in general observed for chickens, too, although effects with chickens were not as large and possibly not as critical commercially. Significant but small increases in toughness were produced by increasing either scalding temperature or scalding time within the commercial ranges. The ultimate toughness after aging increased with extent of beating action incurred by the carcass during feather removal. Beating exerted its greatest toughening effect when applied immediately after slaughter. Beating delayed 1 to 3 hours after slaughter had less effect. Determinations of toughness as a function of temperature and time of aging showed that most tenderization takes place within 4 hours at chill temperatures. Very little occurs after 12 hours. No appreciable tenderization occurred at 0° F. over a 4-month period, but significant tenderization took place in frozen carcasses held at 25° to 27° F. for several days.

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Tenderization arrested by freezing proceeded at about a normal rate on thawing. Cutting up the carcass in the early post-mortem period had a small toughening effect. Results support recommendations for minimum scalding and heating treatments consistent with complete, economical feather removal, and for an adequate aging period, which potentially can be imposed either in the chilling, frozen storage, or thawing steps. (See page 25.)

Color indices *White potato granules*

Color standards for white potato granules. G. C. Nutting, A. M. Smith, B. A. Brice, and M. Simon.

Color is generally an index of over-all quality of potato granules, with darker colors associated with scorched or otherwise improperly processed granules. A color specification based on the spectral reflectance of selected granule samples has been incorporated into the military specifications for white potato granules. Three stable color standards, representing the borderline of acceptability and typically good and typically poor granules, have been prepared. Twenty-five sets of these standards have been transferred to the Quartermaster Food and Container Institute for the Armed Forces for use by QM inspectors and for loan to commercial producers of granules. Inexpensive, technically adequate illuminators and containers have been devised for comparison of granule samples with the color standards. (See page 30.)

Fats in food *Medical observations*

Clinical and epidemiological observations on the influence of fats in the diet, and other clinical observations relative to atherosclerosis and diet. Frederick J. Stare, M.D.

Although most epidemiologists would agree that the differing incidences of coronary artery disease in various population groups are related to a differing mode of life, it has not been conclusively established that dietary factors, and specifically total fat intake, are of primary etiological importance. There is no doubt that patients transferred from a self-selected diet to a purified formula-type diet high in linoleic acid will usually display a decrease in serum cholesterol level. This apparently is sustained for as long as the formula diet is fed. Further, these formula diets are not of practical importance for the public at large. Interestingly, those that have been most effective have not been low in fat—rather, they have been high in fat. Little information is available concerning the supplementation of ordinary American diets with oils rich in essential fatty acids. In general, adults who are not overweight, without any family history of early death from heart disease, and with relatively low levels of serum cholesterol (in the range of 175-225 mg. per 100 cc.) need make no changes in their diet assuming they already consume a variety of foods providing a well-balanced diet. Obese individuals and nonobese individuals with consistently elevated cholesterol levels have somewhat more reason to attempt to lower them, particularly if there is a family history of early death from cardiovascular disease. Individuals who have had a "coronary" are really in the class of "sick patients," and recommendations for them should be on an individual basis and should come only from their doctor. (See page 33.)

Storage study *Freeze-dried soup mixes*

Storage stability of freeze-dried soup mixes. J. J. Wuhrmann, C. O. Chicester and Marion Simone.

Dehydrated vegetable soup mixes were prepared from conventionally dehydrated vegetables and from freeze-dried vegetables. These mixes were compared organoleptically as to (a) original flavor and (b) storage stability under different conditions of storage. Freshly prepared soup mixes made from freeze-dried vegetables were judged higher in quality with less off-flavor than those prepared from dehydrated vegetables. The effect of storage at elevated temperatures increased the off-flavor scores of both types of mixes similarly. Initial flavor differences were maintained throughout the three-month storage period. The effect of packing under nitrogen was to first decrease the off-flavor scores, but as storage time progressed the effect was reversed. Dehydration rates of freeze-drying for various vegetables are presented. Rehydration rates were significantly faster, and the water uptake ratios were higher for freeze-dried than for conventionally dehydrated vegetables. (See page 36.)

Fats in food *Processing aspects*

Processing food fats. J. H. Sanders.

Most domestic vegetable and animal fats as produced from their source require some "refining" or modification to meet the requirements of distribution, end-use or palatability. This "refining" is accomplished in a variety of process steps applied by the manufacturer of food fats. Constituents of raw fats requiring removal or modification, the processes employed, and the general effects of these processes are described. Described also are the manipulations of certain processes such as hydrogenation and interesterification that can produce specific characteristics in end-products. Flow charts of the processes are provided. (See page 41.)

Fats in food *Consumption aspects*

The visible fats in our diet. Karl F. Mattil.

This article discusses: The trends in the consumption and composition of the visible fats (shortenings, margarine, butter, salad oils, etc.) in our national diet; the historical development of our present shortenings and margarine; economic and other factors that have influenced the tremendous increase in consumption of vegetable oils and vegetable oil products in this century. (See page 46.)

Fats in food *Tests with animals*

Effects of dietary fat and cholesterol on experimental animals. J. Stamler, M.D.

A report on recent findings together with interpretative comment. An extensive bibliography is included. (See page 50.)

Radiation as pesticide *Grain*

Irradiation of important grain-infesting pests: order-of-death curves, and survival values for the various metamorphic forms. R. C. Nicholas and D. E. Wiant.

Results of a study undertaken to determine the minimum lethal ionizing radiation requirements to kill the metamorphic forms of various species of grain-infesting pests are reported. Previously published work has shown that radiation is capable of killing many species of insects; however, because all the forms of all the insects have been killed, with few exceptions, at the doses used, minimum requirements are not known. Twelve grain-infest-

ing pests, including two non-insect species, were treated with 1-m.e.v. electrons at various doses to determine the lethality of the treatment to the metamorphic forms and to determine sterility effects on the adults. Order-of-death curves, where obtained, verify the sigmoid shape. In general, graded resistance is exhibited, within a species, increasing with development stage of the insect from egg to adult. Of the insect species, the moths show the highest radiation resistance. Pests covered by the study include: confused flour beetle, rice and granary weevils, saw-toothed grain beetle, Cadelle, Angoumois grain moth, Indian-meal moth, Mediterranean flour moth, lesser grain borer, yellow mealworm, a mite, and a psocid. (See page 58.)

Grading procedure *Raw, canned tomatoes*

Procedures for determining grades of raw and canned tomatoes. Amihud Kramer, B. A. Twigg, and B. W. Clarke.

Procedures for raw tomatoes are based on the yield that can be expected in terms of the canned product, work required in in-plant trimming and sorting, and anticipated quality level of the trimmed and sorted product. A score of 100 may be assigned to samples which would yield top fancy finished products with no trimming or sorting. Deductions for unusable fruit (culls) are made in terms of per cent by weight, and for tomatoes requiring trimming as per cent by count divided by three. A third deduction may be made on the basis of color as determined by the use of the Hunter color-difference meter. The procedures for canned tomatoes are also on the basis of an overall score of 100, with maximum scores for the specific factors of quality as follows: Color—20, wholeness—45, defects—10, and flavor—25. The distribution of grade points among these factors was determined from multiple regression analyses of consumer panel data. (See page 62.)

Fats in food *Factors affecting tolerance*

Fats make good foods—where and why are the margins? C. G. King.

Fats of many kinds and great complexity are characteristic of all living organisms and the human body, like others, is capable of adjusting a great variety and wide quantitative range of lipid materials into its normal functions. As with other nutrients, the margins of relative safety and optimum intakes over a long-time interval are not well established. Few if any other areas of nutrition research are more in need of intensive study. A well balanced diet normally includes a variety of edible fats within the range of about 20 to 40% of total calories. The tolerance range for carbohydrates apparently is even greater, and for the protein, distinctly lower but more critical. The advantages in flavor, satiety, consistency, appearance, economy, convenience, caloric efficiency, and practical sources of vitamins and essential fatty acids can be achieved readily within wide ranges of intake from both plant and animal foods. The latter are especially important, however, as sources of good quality proteins, water-soluble vitamins, minerals and flavor. The cholesterol content of edible fats normally does not constitute a hazard because of the body's capacity for adjusting its own synthesis and disposal. Research is needed to establish the significance of a great number of variables that affect fat tolerances and advantages, e.g. ratios of fatty acids ingested, caloric balance, hormone balance, clotting control, exercise, genetic pattern, chemical and infection stresses, quality and quantity of protein eaten, and the intake of several vitamins (e.g. B_6, C and choline) and minerals (e.g. Mg, Ca, K & Na). (See page 66.)

Packaging *Water-vapor permeability of films*

Factors affecting water-vapor transfer through food-packaging films. M. Karel and B. E. Proctor.

Standard tests for water-vapor permeability of food packaging materials are performed at elevated temperatures and humidities. Results of these tests are frequently extrapolated to other ambient conditions on the basis of an assumed linear relation between water vapor pressure differential and the transfer rate. In order to study the validity of this assumption and to determine the factors affecting water-vapor permeabilities of food packaging materials, experiments were performed at several conditions of temperature and humidity, using gravimetric and hydrometric methods of permeability measurement. Materials studied included commonly used packaging materials as well as some of the newer types of plastic films. Experimental results obtained in these studies are presented and their practical and theoretical significance discussed. (See page 69.)

Radiation preservation *Whole eviscerated chicken*

Gamma ray pasteurization of whole eviscerated chickens. J. N. McGill, A. I. Nelson, M. P. Steinberg and L. L. Kempe.

Dressed chickens show microbiological spoilage after a short holding time even at refrigerated temperatures. Although meat can be sterilized by ionizing radiations, the process has several disadvantages. Deleterious chemical reactions are produced during irradiation and increase upon storage. Pasteurization doses of ionizing radiations with subsequent refrigeration storage tend to minimize these disadvantages and at the same time increase the refrigerated storage life of chickens. This study was initiated to investigate the effect of pasteurization doses of gamma rays on microbiological and organoleptic quality of plastic-film packaged, whole, eviscerated chickens subsequently stored at refrigerated temperatures. Two gamma ray sources, Co 60 and partially spent fuel elements, were used in this study. The effectiveness of the two sources was investigated in separate experiments using two dosage levels. In the third portion of this study, the two sources were statistically compared at one irradiation level. After irradiation the chickens were stored at various refrigerated storage temperatures for several time intervals prior to examination. Results of the microbiological and organoleptic analyses are reported. An extension of the storage life at temperatures 34° and 40° F. were found. Irradiation flavors at the dosage levels used in this study were not found to be a problem. However, at the high irradiation level, rancidity developed in storage before the chickens were spoiled due to microbiological activity. Rancidity was found to develop at a more rapid rate at the lower storage temperatures. For the factors investigated in this work, use of Co 60 resulted in a significantly smaller population of microorganisms after storage than did use of fuel elements. (See page 75.)

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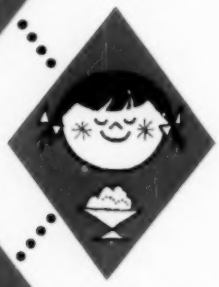

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What Is a Food Technologist?

Further Comment on the Industry-College Conference, 1958, at Allerton House

Bernard E. Proctor

Department of Food Technology
Massachusetts Institute of Technology
Cambridge, Massachusetts

It is all too easy to permit auspicious events to slip away from us and become mere records in the files.

The 1958 Allerton House Conference on Food Technology Teaching was one of the most important and significant steps ever taken by the Institute of Food Technologists. It should do more to help both food technology and those in this profession than any one move which has ever been taken since the inception and establishment of the Institute of Food Technologists. This meeting of a representative group of upper-echelon food industry employers of food technologists, spending three days with the representatives of the majority of the universities and colleges teaching food technology in order to outline what the food industry feels is essential in the training of future food technologists, has been most advantageous to all concerned. The great decisions made at this meeting must not be allowed to fall into the category of "interesting ideas." They are decisions that will "energize" the future of food technology as a profession.

The Allerton House meeting clarified misunderstandings which many in the teaching professions may have had concerning what a food technologist is expected to be and to have in the way of technical attributes by their future employers in the food industries. Likewise it provided an opportunity for industry participants to appreciate the problems of those who are attempting to train food technologists. Above all it convinced everyone that four years is scarcely enough time to cover basic required scientific disciplines at levels of progress which should guarantee graduates trained to the degree necessary for a professional man.

BUILDING ON THE BASIC DISCIPLINES

The conference also indicated very clearly that professional competence in specific commodity areas, in the opinion of industry representatives, can only be attained by building on a foundation of extended training in mathematics, chemistry, physics, biology, and engineering which are taught at the college level by those in departments provided for this purpose.

It should be noted that this is in contrast to the view, still held by a few teachers in the educational field, that starting from the college freshman year students in food technology should be trained almost exclusively in the arts and techniques of a single food commodity area to the exclusion of all else. Apparently the industrial advisors approve the recent citation of a prominent agricultural educator who said, "Training in repetitive procedures is bound to result in the perfection of education in obsolescence." What the food industry needs today is young technical men *who can think*. To this doctrine we can all subscribe. How can we attain such a high purpose?

The basic requirements for the foundation training of a food technologist as defined at Allerton House is a seven league step toward this goal.

Here they are:

	Semester Hours		*Semester Hours*
Chemistry:		Microbiology	5
Inorganic	5	Food Bacteriology and Sanitation	5
Qualitative	5	Physics	10
Quantitative	5	Food Processing	12
Organic	5	Unit Operations	10
Physical Chemistry	8	English	6
Food Chemistry–Analysis	4	Speech and Technical Writing	3
Biochemistry and Nutrition	6	Economics	3
Mathematics:		Humanities and Social Science	12
Algebra	3	Physical Education and Military Training	8
Analytical Geometry	3		
Calculus	8	*Total*	131
Biology	5		

Re-read this curriculum. It represents the elements of sound scientific training. The mind that masters these courses will be a disciplined mind.

This backbone of scientific training may be *amplified* in numerous and varied directions to accomplish specific purposes, or supplemented by other scientific disciplines—but the fundamental core of essential studies cited above should not be subject to deletions in order to provide specialization.

THE ARGUMENT CAN END—WE HAVE DEFINED FOOD TECHNOLOGY TRAINING

Many educators now have the data necessary to convince their academic administrative officers that certain minimum requirements are necessary to present a properly qualified four-year course in food technology and what these elements of the curriculum should be, both qualitatively and quantitatively, to constitute a basis for professional recognition. These requirements should also indicate to all concerned that no educational institution having less than a four-year curriculum should consider their graduates as food technologists. In the opinion of many members of IFT, it should be necessary for this base of minimum requirements to have been successfully met for anyone to assume the title of food technologist. This need not lead us into inflexibility—to the point where we refuse to recognize instances of extended experi-

ence or training in collateral professional activities that provide equivalent qualifications. But our newly established definition of a food technologist can be used as a standard.

WE NEED TO "TELL THE WORLD"

Having arrived at this stage of professional progress, we as food technologists have reached the plateau attained by the chemical engineers some decades ago when they as an organized group began to crystallize what a chemical engineer was, or should be. This was partly to tell *industry* what could be expected of a man called a chemical engineer. It also made it possible for the academic fraternity to know what was expected so the necessary curricula could be established to enable logical standards of educational training for this sort of human end product.

Is it not time that we food technologists take these same steps and indicate through our professional society, the Institute of Food Technologists, what may be expected of food technologists in the future as to background and training?

There has been considerable confusion in the minds of many potential employers of food technologists regarding what one should expect in a food technologist, and this clarification may now be made to the advantage of all concerned. The sooner and the clearer this picture may be presented to the executives of the food industries the faster will be the progress of food technology in the future.

A WORD IN APPRECIATION

The sincere appreciation of the Institute of Food Technologists is due to the members of the advisory group of food industry employers and food industrial associations, mostly members of the IFT themselves, who gave so generously of their time and effort in establishing the foundations which should be adopted as a criterion for the future education of food technologists.

Let it be said again: it is all too easy to permit auspicious events to slip away from us. We have made a great beginning. Let us keep the results of the Allerton House conference in our active files—or, better yet, prominently in our minds.

Soil and Water Conservation an Important Theme of Agricultural Research Institute Annual Meeting

Ira I. Somers
Liaison Representative from the Institute of Food Technologists

No one needs to be told that soil and water form the ultimate basis of the food industry and these topics received great emphasis at the Seventh Annual Meeting of the Agricultural Research Institute in Washington, D. C. in October. The Agricultural Research Institute, it should be recalled, is affiliated with the Agricultural Board of the National Academy of Sciences, National Research Council. Established in 1951, the Institute serves, to quote its formal statement, "as a means of organizing the scientific talents of industry, public agencies, scientific societies, and private institutions in support of the Agricultural Board, and to provide a forum for unrestricted discussion of common problems." Its supporters see in it a means of disclosing important research needs in the agricultural field, and of mobilizing resources for attack on the problems so revealed. Further information about the Institute was given in Dr. Gunderson's report of the 1957 Meeting (Food Technol. *11*, No. 12, 20 a [1957]).

The program of the October 13-14 meeting, held in Washington, D. C., consisted of three half-day general sessions in addition to the annual business meeting. Included were three panel presentations and several addresses on subjects ranging from the public school system to the Pioneering Laboratories of the U. S. Department of Agriculture.

At the October 13 luncheon, members and guests heard a thought-provoking address by Dr. Detlev W. Bronk, President of the National Academy of Sciences. Dr. Bronk reminded his hearers that science is not to be thought of merely as a means to material advance and national defense but as an aid in bringing a better and nobler way of life to all peoples everywhere.

Of particular interest to food producers and processors was a panel discussion on mobilizing research for progress in soil and water conservation. The Agricultural Board had adopted on October 12 a policy guide urging the allocation of funds to three interdependent types of research: independent, interagency cooperative, and special laboratory. The four most important research needs concerning water as a factor in food production were listed as the physics of water loss from surfaces, run-off hydrology and irrigation management, the dynamics of water in plants, and the response of plants to water deficits.

New officers elected were Dr. Burt Johnson of the National Cotton Council, President, Dr. Charles H. Mahoney of the National Canners Association as Vice President, and Dr. M. B. Gillis of International Minerals and Chemical Corporation as Secretary. The

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Committee on Agricultural Public Relations, under the chairmanship of C. L. Rumberger of the H. J. Heinz Company, will continue its program. Among other actions taken by the Institute was a resolution commending the Department of Agriculture for establishing local study groups on research facility needs in soil and water conservation under the auspices of state Experiment Stations. The importance of this subject in crop production is obvious; in addition the food processing industries use large quantities of water, and often produce comparable quantities of waste which must somehow be disposed of without polluting natural waters or destroying the usefulness of land. Thus it is clear that food technologists have an interest in these problems and should wish agricultural scientists every success in solving them.

Twenty-one Nations Participate in Worlds Poultry Congress

W. J. Stadelman
Purdue University, Lafayette, Ind.

THE ELEVENTH WORLDS POULTRY CONGRESS met in Mexico City, D. F., September 20 to 28, 1958. The 126 scientific papers were presented by workers from 21 countries. These were representatives of 46 countries at the Congress. The papers presented covered a wide range of subjects many of which would be of interest to E. F. T. members. Proceedings of the meeting will be published in book form.

Professor J. R. Cavers of Ontario Agricultural College presented results of extensive studies comparing commercially graded egg qualities to broken-out egg quality measurements on the same eggs. The Canadian researchers were able to get remarkably good differentiation of broken-out qualities by commercial candling. Dr. N. R. Knowles of the British Egg Marketing Board presented a report on egg cleaning methods and their effect on quality. His conclusions were that only drycleaned or nest-clean eggs should be stored. Wet cleaning methods employed resulted in an increased loss due to bacterial contamination of the contents of the eggs.

An interesting paper on sources of bacterial contamination of shell eggs was presented by R. G. Harry of Donshire, England. It was found that type of litter and particularly the nesting material greatly influenced the numbers of microorganisms on "clean" eggs. Another paper on eggs quality was presented by Lusiano Crispin of Mexico. He reported the effects of altitude on quality of eggs laid by three strains of hens. The hens were kept at experiment stations with altitudes of 16 meters and 2,675 meters. The hens at low altitude laid larger eggs than comparable hens at the high altitude. The high altitude hens laid eggs with heavier shells and with a higher incidence of blood and meat spots than the low altitude hens.

Workers from U.S.D.A. presented several papers of interest to I.F.T. members. Elsie Dawson, Institute of Home Economics, Beltsville, Md., reported on the use of poultry meat and eggs in U. S. households. A. W. Brant of Agricultural Research Center, Beltsville, Md., presented some interesting comparisons on flavor of the modern chicken fryer with the chicken of 1930 —no significant differences in flavor were noted. Hans Lineweaver, Western Utilization Research and Development Division, Albany, California, discussed factors affecting tenderness of poultry meat.

There were many other interesting papers on nutrition, genetics, pathology, physiology and general management of poultry. At the business sessions Dr. H. H. Alp of Chicago was elected president. The next international congress was scheduled for 1962 to meet in Australia. Everyone in attendance enjoyed this visit to Mexico City and congratulations are due our hosts for a well conducted Congress.

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Aluminum Foil Packaging – Developments in Overwraps

Report No. 18 of a Series by Reynolds Metals Company

WHEN the old-fashioned grocer wrapped a box of kitchen matches in brown paper – that was an early overwrap. But packaging in the modern sense means *pre*-packaging. It was only when the product reached the grocer already wrapped, with the brand name printed on the wrapper, that the age of the overwrap began as we know it today.

Then as now, product protection and identification were the objectives, and today's carton overwraps demonstrate the tremendous progress made along both lines. Reynolds Aluminum Foil overwraps, applied to packages by automatic machines at rates exceeding 100 units per minute, are a far cry from the early paper wraps applied by hand.

The first step in protection, beyond plain paper, was waxed paper. Then came other materials – plastic films such as cellophane and cellulose acetate, and aluminum foil. This latter, which the Reynolds Metals Company was first to develop into overwraps, has proved itself superior in protective qualities – superior even to the newer plastic films.

The best demonstration of this superior protection is by the water vapor transmission rates of various overwraps on finished packages. The comparative rates are shown in the accompanying chart. Here the water vapor transmission rate is expressed in grams of moisture per 100 square inches per 24 hours, when subjected to conditions of 100°F. and 95% relative humidity. Overwraps were on cartons of the conventional type. The various materials are identified on the chart, but a more detailed description of the foil materials follows:

1. 0.00035" aluminum foil glue laminated to a paper. This was the first aluminum foil overwrap and it was necessary to seal it to the carton with an adhesive. Such a wrap is commonly known as "Titewrap".
2. Heat-seal coated 0.00035" aluminum foil glue-laminated to paper. This material not only provided greater water vapor transmission protection through heat sealing, but enabled increased production on automatic packaging machines.
3. Reyseal. This is 0.00035" aluminum foil wax laminated to a porous tissue. The wax not only provides increased water vapor protection, but is also heat sealing as it strikes through the tissue. Intermediate papers or films are used to provide greater strength when needed.
4. Super Reyseal. This is heat-seal coated 0.00035" foil which has been extrusion laminated with polyethylene to a grease proof paper and this combination then wax laminated to a porous tissue. With this Reynolds overwrap, heat sealing is accomplished on all surfaces to provide the greatest protection for the most critical products.

To be noted, on the chart, is the significant decrease in water vapor transmission rate from waxed paper to cellophane to the first simple aluminum foil overwrap and finally to Reynolds Super Reyseal (material 4). In addition to superior moisture protection, all these foil overwrap materials also provide low gas permeability, positive light barrier and grease resistance. Further data on these properties will be found in Reports Nos. 2, 3, 4 and 6 of this series.

As stated above, the second objective of overwraps, besides product protection, is identification – which today has graduated into a new science of shelf display and merchandising. This required the development of new techniques in color printing on foil, and again Reynolds pioneered.

Finally, even with perfected materials and highly developed design and printing facilities, this age of automation required ever farther advances in machinery and equipment systems. In this field, too, Reynolds has pioneered. Your Reynolds representative offers expert counsel on this as on other phases of packaging. Call the nearest Reynolds sales office. Or write **Reynolds Metals Company,** Richmond 18, Virginia.

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IFT NEWS

FUTURE MEETINGS FOR FOOD TECHNOLOGISTS

1959	
February 13-15	30th Fact Finding Conference, Sponsored by the Institute of American Poultry Industries, Municipal Auditorium, Kansas City, Missouri
February 21-24	Convention of the National Canners Association, Conrad Hilton Hotel, Chicago, Illinois
February 26-27	7th Annual National Dairy Engineering Conference, Kellogg Center, Michigan State University, East Lansing, Michigan
March 1-5	Convention of the National Association of Frozen Food Packers, Conrad Hilton Hotel, Chicago, Illinois
March 4-6	Southeastern Conference on Better Foods, The Georgia Center for Continuing Education, University of Georgia, Athens, Georgia
March 31-April 2	Annual Meeting of the Research and Development Associates, Food and Container Institute, Inc., Statler Hotel, Washington, D. C.
April 20-22	American Oil Chemists Society Spring Meeting, Roosevelt Hotel, New Orleans, Louisiana
April 28-May 1	Annual Convention of the Institute of Food Technologists, Australia, Mayer Chalet, Warburton, Victoria
May 17–21	**Nineteenth Annual Meeting of the Institute of Food Technologists, Bellevue-Stratford Hotel, Philadelphia, Pennsylvania**
June 11-12	Canadian Institute of Food Technology, 2nd National Conference, Royal Hotel, Toronto

1960	
May 15-19	**Twentieth Annual Meeting of the Institute of Food Technologists, Fairmont Hotel and Masonic Temple, San Francisco, California California**
1961	
May 7-11	**Twenty-first Annual Meeting of the Institute of Food Technologists, Hotel Statler, New York, New York**
1962	
June 17-20	**Twenty-second Annual Meeting of the Institute of Food Technologists, Amercana Hotel, Bal Harbor, Miami Beach, Florida**

An open invitation is extended to readers of FOOD TECHNOLOGY to send in to the Editorial Office, 11606 South Bell Avenue, Chicago 43, Illinois notices of annual or national meetings of interest to food technologists.

REGIONAL NEWS

MINNESOTA

Gerald F. Doolin, director of sanitation, National Confectioner's Association of the United States spoke on the "The Continual Rat-Race" at the November 17th meeting of the Minnesota Section of the Institute of Food Technologists. Mr. Doolin reviewed the habits of the two rodent pests—rats and mice—and noted that extensive studies of these rodents have been made by the Fish and Wild-life Service in Colorado and at other locations. The speaker emphasized the disease-spreading ability of rodents.

Slides shown by Mr. Doolin depicted methods of structural control of rodent invasion, as well as the importance of general sanitation in food plants. In his final remarks the speaker stated that pest control is a top-management problem, and that specific written instructions concerning sanitation duties should be handed to all concerned if a coordinated control plan is to be carried out.

Prior to the dinner meeting members toured Land O' Lakes Creameries, Inc. Central Processing and Packaging and the Research Departments. The tour gave members an opportunity to observe the operation of one of the largest butter printing units in the United States, a continuous cheese processing and packaging unit, and a non-fat dry-milk packaging unit.

The tour terminated in the research department where Mr. Raymond Mykleby, supervisor of laboratories, explained Land O' Lakes' research program.

The Minnesota Section will again entertain wives and sweethearts at the January 21, 1959, meeting. Miss Mary Kimball, head of new products kitchens, home service center, The Pillsbury Company, will speak on "Grandmother's Kitchen Cupboard."

—Franklin L. Sorensen Jr.

CHICAGO

Our December meeting, ladies night, was a great success for technical and lay audience alike. Mrs. Judith Pauzat of the Hotpoint Home Economics In-

New Academic Press Books

Advances in FOOD RESEARCH
Edited by E. M. Mrak and G. F. Stewart
Volume 8
1958, 437 pp., illus. $12.00

BIBLIOGRAPHY OF FOOD
By E. A. Baker and D. J. Foskett
1958, 331 pp. $11.00

PRESSURIZED PACKAGING
By A. Herzka and J. Pickthall
1958, 406 pp., illus. $12.00

TRACE ELEMENTS
Proceedings of the Conference Held at the Ohio Agricultural Experiment Station, Wooster, Ohio, October 14-16, 1957
Edited by C. A. Lamb, O. G. Bentley, and J. M. Beattie
1958, 410 pp., illus. $12.00

YEASTS
Edited by W. Roman
1957, 246 pp., illus. $7.50

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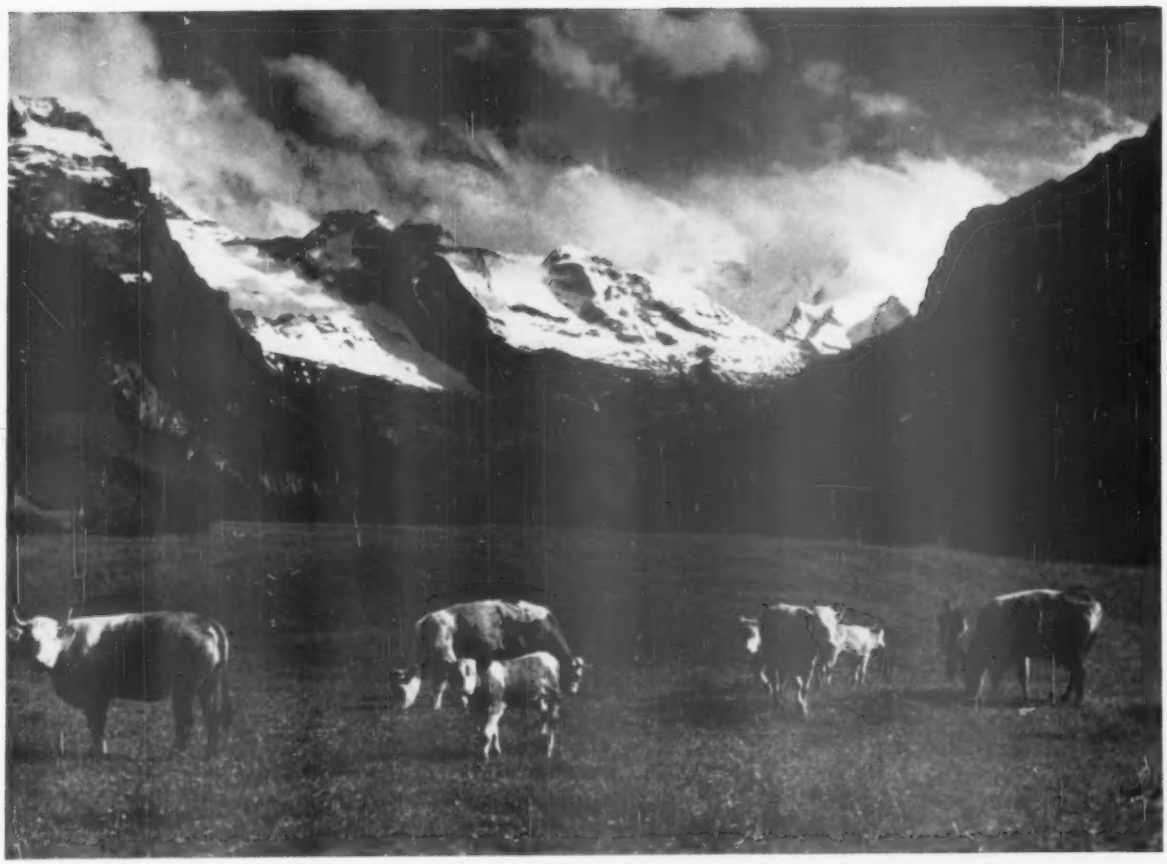

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stitute was the speaker. She has done major research in the field of electronic range cooking. Mrs. Pauzat demonstrated an electronic range and gave an insight into electronic cooking by preparing food from a typical menu right on the spot. Mr. D. W. Quirk, Hotpoint Technical Staff member, also attended and answered questions on the electronic range.

The Section was honored by the presence of Dr. Aksel G. Olsen, president of IFT, Dr. Ray Wakefield, president-elect, past-presidents George Garnatz, Dr. Arthur Prater, IFT treasurer, and many other out-of-town guests.

Our next meeting is scheduled for January 12, 1959. The speaker will be Mr. Lyle Powell, Jr., Packaging Director, Jewel Tea Company, Barrington, Illinois. Mr. Powell will discuss various aspects of modern packaging, emphasizing trends in package design and new package forms resulting from merchandising research and consumer motivation studies.

Phi Tau Sigma

The University of Massachusetts Chapter of Phi Tau Sigma, the Food Science Honor Society, elected the following officers for 1958–1959: President—Prof. John W. Zahradnik, Department of Agricultural Engineering; Vice-President — Prof. Warren Averill, Department of Food Technology; Secretary—Prof. F. John Francis, Department of Food Technology; Treasurer—Prof. Carol S. Wisnieski, Department of Bacteriology; National Councilor—Prof. G. E. Livingston.

DIXIE

The Dixie Section of IFT held its 10th Anniversary meeting—the 62nd since the organizational meeting on October 30, 1948—at Georgia Tech in Atlanta, Georgia, on November 21. We were honored to have our national president, Dr. Aksel G. Olsen as our speaker. He came to America from Denmark at the age of 16 and attended colleges in Nebraska and Minnesota. He began work at the Postum Company, now the General Foods Corporation, in the early 1920's. After a distinguished career, he retired in 1957, his position being that of Technical Director, Research Planning, General Foods Corporation, Research Center, Tarrytown, New York. He had spent 34 years in research for General Foods and participated in their many public service projects as well.

President A. G. Olsen, IFT

Dr. Olsen spoke on "Industrial Research and Research Planning" and also gave a brief history of Food Technology. His definition of industrial research is the organized application of science to develop useful, profitable solutions to previously defined

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Starch Chemistry for the Food Technologist*

(Manuscript received May 31, 1958)

L. M. Waldt and D. Kehoe
Morningstar-Paisley, Inc.,
New York, N. Y.

KNOWLEDGE OF STARCH and its chemistry is of great importance to the food technologist and processor because this product is used so widely in the manufacture of food products. For example, when a food processor needs an inert, neutral, edible filler; or when liquids such as water, milk, or juices are to be thickened; or where gels are required, there is usually a starch that will provide the desired characteristics.

The food industries comprise one of the largest consumers of starches and starch products, using more than 30% of total starch production. Table 1 lists a number of common foods to which starches provide their desirable properties and characteristics. The starches commonly used in these foods include: potato, corn, amioca, wheat, sago, rice and arrowroot and tapioca flour. This paper will attempt to present a short review of starch chemistry, with particular emphasis on the raw starches utilized in food products. Subsequent papers in the series, will discuss, in turn, processed and modified starches and pregelatinized starches and their characteristics that affect food processing.

TABLE 1
Representative foods containing starch

Custards	Crackers	Pie Fillings
Sauces	Processed Meats	Cake Fillings
Gravies	Canned Goods	Salad Dressings
Soups	Baby Foods	Confectionery
Souffles	Powdered Mixes	Frozen Foods
Breads	Dessert	Convenience Foods
	Pudding	
Cookies	Cake	Ice Cream Cones

Characteristics of starches. The food technologist is usually most interested in the colloidal properties of a particular starch in an aqueous dispersion. Of these properties, the following are the most important: sol clarity, organoleptic characteristics, viscosity, color, flow characteristics, gel and adhesive strength, and film properties. Table 2 lists the functions of starch dispersions and shows how they are used in particular foods. The first four of these functional uses of starch are dependent upon the colloidal nature of the starch hydrosols. These sols are strongly hydrophilic and structurally strong, forming quite permanent gels.

The inherent physical properties of any native raw starch, as distinguished from a modified starch, are principally dependent on its genetic origin which determines its granule size, amylose-amylopectin ratio, and the molecular weight of the amylose and amylopectin polymers *(3)*.

TABLE 2
Functions of starch in typical foods

Function	Foods
Thickening	Gravies, Sauces, Pie Fillings, Soups
Gelling	Gum Drops, Puddings (cooked)
Stabilizer	Beverages, Syrups, Salad Dressings
Binder	Processed Meat Products
Moisture Retention	Cake Fillings, Confectionery Items
Coating Agent (Dusting)	Breads, Confectionery Items
Moulding	Gum Drops, Jellies, Confectionery Items
Diluent and Flow-Aid	Baking Powder Formulations

Starch chemistry. Starch occurs in the form of white granules which are usually made up of an organized structure containing both a linear polymer (amylose) and a branched polymer (amylopectin). Each granule comprises a uniform mixture of the two types of polymers, which are oriented and associated in a crystal-like lattice. They are insoluble in cold water and relatively resistant to naturally occurring hydrolytic agents. In starches from some plants, such as potato, the amylopectin may be esterified with a small amount of phosphate.

The two polymers differ in molecular weight and chemical structure: amylose consists of 200 to 1000 glucopyranose units joined through alpha 1–4 glucosidic linkages, whereas the branched or ramified polymer, amylopectin, is made up of chains of 1500 or more glucopyranose units. The linear polymer and the longer branches of the non-linear polymer exhibit a pronounced tendency to orient and associate with

TABLE 3
Physical and chemical properties of raw starches

Starch	Average granule size (microns)	Temp. at which gelat. begins 5% sol.		Amylose content, %	No. of glucose units per molecule amylose
					Periodate oxid. det.
		C	F		
Potato	33	63.9	147	22	980
Corn	15	80.0	176	28	490
Tapioca	20	62.8	145	18	980
Amioca	15	73.9	165	0–4	
Arrowroot	30–45	75.0	167	20	
Wheat	21	76.7	170	25	540
Rice	5	81.1	178	17	
Sago	31	73.9	165	27	420

TABLE 4
Physical properties of raw starches

Density of starches completely dehydrated		Dimensions of starches			
Starch	Density	Starch	Gran. diam. (mm.)	Gran. volume $(mm.)^3$	Surf. area Sq. m./100 g.
Corn	1.620	Rice	0.004	3.35×10^{-8}	99.4
Wheat	1.629	Corn	0.014	1.53×10^{-6}	27.9
Potato	1.648	Potato	0.040	1.72×10^{-5}	11.9

Specific heat (hydrated starch)—0.3299–0.399 at 0°–60° C.
Temperature coefficient of expansion—3.50×10^{-4} at 20° C.

* Presented at the Eighteenth Annual Meeting of the Institute of Food Technologists, Chicago, May 26, 1958.

other linear molecules *(4)*. The physical and chemical characteristics of various starches, listed in Tables 3, and 4, are of importance to the food technologist.

Starch gelatinization. The starch granules in a sol swell progressively as the temperature is raised to the range between 60° and 70° C. The temperature at which gelatinization begins is a characteristic of each particular type of starch. When heated above the temperature of gelatinization, the granules undergo an irreversible, sudden, rapid swelling and the viscosity of the suspension increases greatly to form a paste or a sol. On further increase of temperature, the final phase of the reaction is indicated by a rapid diffusion of starch from some granules and by the rupture of others, which leaves numerous formless sacs. Upon cooling, there is further stiffening and gelling of the sol *(4)*.

It is believed that the degree of retrogradation upon cooling is inversely related to the chain-length of the amylose molecule. Tuber starches (except in the case of sago) gel much less readily than corn or wheat, as is expected from the length of the chain of their amylose polymers *(2)*.

There is also a difference in texture between gels formed from longer and shorter-chain amylose because orientation and association are more difficult in the longer chains. The degree of polymer association, which differs with each starch, may also explain, in part, the differences in gelatinization temperatures of different types of starch. This factor is illustrated in Table 3. Furthermore, it is indicated that small granules usually gelatinize at a slightly higher temperature than larger granules *(1)*.

EXPERIMENTAL

The gelatinization process of starch may be followed through the study of viscosity changes and relationships as indicated by a Brabender Viscograph (Standard American Model VI; C. W. Brabender Instruments, Inc., South Hackensack, New Jersey: Brabender Corporation, Rochelle Park, New Jersey.) This instrument heats a starch-water dispersion at a uniform temperature change rate of 1½° C. per minute. It can be adjusted to heat the solution to any given temperature from 25° to 95° C. and will maintain a predetermined temperature for any length of time. The unit will also cool the solution at the rate of 1½° C. per minute from the maximum temperature down to 25° C.

During the heating and cooling cycles, a recording pen charts the solution viscosity continuously in arbitrary Brabender Units vs. time. (100 Brabender Units are equivalent to approximately 180 cps.)

Study of the viscosity data thus recorded yields valuable information concerning the physical changes that may be expected during the processing of a starch bearing product. It may also aid in determining if the starch under study is a native or a modified starch. Some indication of the early processing characteristics of the starch solution is also derived from these charts.

Because these graphs only picture viscosity changes and do not measure other important characteristics and properties of a starch, the food technologist needs supplement his viscosity studies by actual "use" tests in a particular food product or process.

In our laboratories, Brabender viscosity studies are standardized upon a 450 ml. water increment and varying the starch concentrations to produce a reading near the middle range of the instrument.

Procedure. The calculated weight of starch on a dry basis is slurried into 450 ml. distilled water corrected for moisture in the starch. Slurry temperature is then adjusted to 25° C., and the slurry is then poured into the bowl of the instrument. The instrument control should be set as follows: heat at 1½° C. per minute for 45 minutes to a maximum of 92½° C. Maintain 92½° C. for 15 minutes. Cool at 1½° C. per minute to 25° C. (i.e. 45 minutes). Hold for 15 minutes at 25° C.

Several viscosity characteristics are noted from the viscograph chart:

A. *Pre-Gel Period.* This is the elapsed time prior to the first indication of viscosity increase. This time (in minutes) multiplied by 1.5 plus 25 equals the initial gel temperature.

B. *Gel Period.* This is the time interval during which hydration and swelling of the starch granules proceeds. This period starts with the first indicated rise of viscosity and ends when the highest viscosity is attained during the heating cycle. This greatest viscosity is called "Peak Viscosity." Peak Viscosity is of importance in calculating maximum power requirements for equipment in which starch is cooked.

C. *92½° C. Viscosity.* The recorded Brabender viscosity at 92½° C. and after holding the solution temperature at this temperature for 15 minutes yields important information concerning the characteristics which may be exhibited during an actual "cook" employing the starch.

D. *25° C. Viscosity.* This is the viscosity of the starch dispersion when the solution reaches 25° C. and is held at that temperature for 15 minutes.

Because the starch is under constant agitation during the foregoing 2-hour cycle of viscosity measurement, the data are not directly applicable to empiric processes. However, the uniformity of test conditions makes the data directly comparable and hence these data are a source of much information with respect to thinning, thickening or gelling of starches when actually processed.

RESULTS AND DISCUSSIONS

Figures 1–4 illustrate 2-hour Brabender viscosity curves for the more important starches used by the

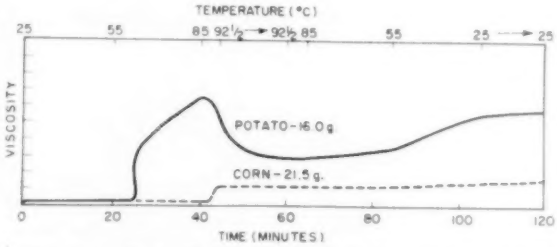

Figure 1. Brabender viscosity curves for potato and corn starches.

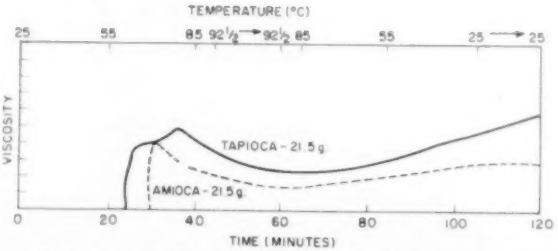

Figure 2. Brabender viscosity curves for tapioca and amioca starch.

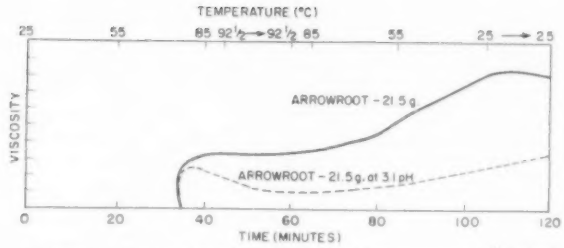

Figure 3. Brabender viscosity curves for arrowroot (neutral and acid conditions)

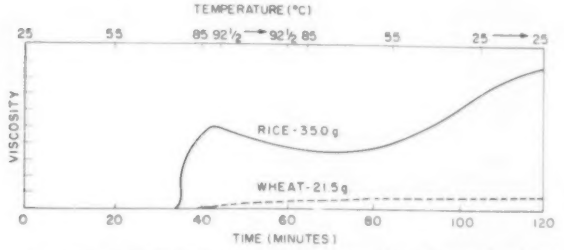

Figure 4. Brabender viscosity curves for rice and wheat starches.

food processor. It is of great importance to realize the limitations of viscosity curves, and an adequate investigation should also include visual and organoleptic observances of cooked starch dispersions and "use" tests. Only by a total investigation of the starch, can the food technologist recommend a particular starch to fit the processor's needs and specifications.

On the other hand, a study of any one viscosity curve will make it possible to provide the basis for uniform food processing when starches are used. In food manufacturing, cooling and heating procedures should be standardized as much as possible. Agitation in processing must be fully controlled.

In the further study of a starch, the other ingredients of a particular food product may be included in the slurry or starch suspension under investigation. Through such an investigation, the results will be more reflective of the properties of the actual end product.

The viscosity curve, in general, does not lend itself readily to the study of the important phenomena that take place in the cooling of starch solutions. These factors include gel formation, set-back, texture, etc.

Visual characteristics. The properties of a starch are dependent upon its molecular shape and dimensions. The process of gel formation, set-back, or retrogradation may be explained in terms of polymer association, especially in the linear amylose fraction present in the starch molecule, as mentioned previously. Table 5 lists some of the visual characteristics of raw starch suspensions. These characteristics may be explained, in part, by the molecular and chemical make-up of the amylose-amylopectin proportion within a particular starch.

As a note of interest, the starch chemist can, through subtle modification of the raw starch by means of mild acid or oxidative treatments, reverse these properties. This type of treatment is responsible for the newer types of processed starches (specialty starches, modified starches, and pre-cooked starches) which fit in even better with the requirements of the food manufacturer. Furthermore, two or more types of raw starches can be blended in varying proportions to reduce gel formation, improve texture, attain better clarity, etc., for example, the properties of corn starch disadvantageous to an acceptable pie filling, may be circumvented with the use of tapioca in a proper blend as a base thickener and stabilizer. Furthermore in this case the cohesiveness of tapioca is balanced by the short, brittle characteristics of corn starch, resulting in a filling with good texture characteristics. The corn cereal taste, of course, is diluted by the extreme blandness of tapioca and the clarity of the filling is considerably improved. Thus, some formulations and recipes for pie fillings, usually call for a blend of ⅔ corn starch plus ⅓ tapioca to achieve the most desirable features for good pies. Many of the modern salad dressing formulations call for blends of starches, as well. The food technologist with full knowledge of the properties and characteristics of starch can then recommend the correct blends to meet with the desires and requirements of the food processor for a particular product.

TABLE 5

Characteristics of raw starch

(Five per cent aqueous dispersions gelatinized and cooled)

Starch	Taste	Texture	Clarity
Potato	Sl. charact. taste	Long cohesive	Clear
Corn	Cereal	Short stiff gel	Opaque
Tapioca	Bland	Long cohesive	Clear to translucent
Amioca	Cereal	Long cohesive	Clear to translucent
Arrowroot	Bland	Short cohesive	Translucent
Wheat	Cereal	Short soft gel	Slightly opaque
Rice	Cereal	Short stiff gel	Slightly opaque
Sago	Bland	Long cohesive	Clear to translucent

In general, root starches gelatinize more rapidly, and at lower temperatures; they yield clearer solutions, taste better, and hold water more tightly. When used with cereal starches, they may exert a stabilizing effect that reduces weeping and syneresis. On the other hand, root and stem starches, except in the case of sago, have relatively weak gel tendencies (primarily, because of the length of their amylose fraction). Therefore the resulting textures of foods that include root starches are on the gummy side or cohesive *(5)*.

CONCLUSION

The basic polymeric foundation of starch chemistry has been reviewed and the properties and characteristics of raw starches used in foods have been outlined. Methods of study and investigation of some starch properties were discussed, with particular

emphasis on the functional needs of the food technologist and processor.

Acknowledgment

We gratefully acknowledge the aid and assistance of Mr. Robert Nebiker, Chief Chemist, Hawthorne Laboratories, Morningstar-Paisley, Inc. for his valued cooperation, particularly in furnishing the laboratory data and Brabender viscosity curves used in this paper.

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Relationship of Naturally Occurring Tartaric Acid to Certain Physical Constants of Concentrated Concord Grape Juice*

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An important criterion of quality control of commercial batch preparations of single strength edible Concord grape juice and concentrates is the total soluble solids content. Analysis of soluble solids content is necessary because the sweetness of the untreated product varies seasonally, depending upon weather conditions. Since a processor endeavors to provide a product of uniform sweetness, varying quantities of added sucrose are required to achieve this end.

Time is necessarily of importance in all plant control testing and for this reason the determination of solids by the conventional analytical method of drying to constant weight has been avoided. Chemists have preferred to use the values obtained by the refractometer and Brix hydrometer. Presence of tartaric acid, the chief organic non-sugar component of grape juice, has not, however, been taken into consideration in establishing these values. It is the purpose of this paper to provide tartaric acid correction tables and thus enable the analyst to obtain trustworthy total soluble solids value by the refractometer and Brix hydrometer methods.

A Brix review of the background will be useful. The instruments just mentioned have been used by previous workers in the quality control of processed food materials. Bendler *(2)* for example, used the refractometer in the batch control of sugars, jams, and fruit juices. Roberts *(10)* used the refractometer for regulating wort Balling, beer Balling, and the alcohol content of other brewery products. The regulation of the specific gravity of tomato products by the Abbé refractometer is shown by Gurley *(4)*. Grape juice processors at present are using the Brix hydrometer to regulate and measure soluble solids content. This instrument is a hydrometer, calibrated directly in per cent by weight of sucrose. When it is used in testing grape juice concentrates, however, inaccurate results may be obtained because of the comparatively high viscosity of this product.

Although both the Brix hydrometer and the refractometer, calibrated to read per cent sucrose, yield identical values when applied to pure sucrose solutions, quality control chemists are not agreed which affords the more reliable result when food products are tested. Gentilini *(3)* reported that the refractometer measured the soluble solids content of wine musts more accurately than did the Brix hydrometer. This observation was confirmed by Barini-Bianchi *(1)*. Miconi *(7)* reported that the soluble solids in wines cannot be accurately determined with either instrument.

The reason for this lack of agreement is that the products referred to above are mixtures of soluble compounds, each of which influence both the Brix

* Based on a dissertation to the Faculty of the Graduate School, Georgetown University, in partial fulfillment of the requirements for the degree of Master of Science.

and the refractometer readings to a different degree. In order to refer the Brix or refractometer reading of a fruit product to total soluble solids, it is necessary at least to correct for the principal non-sugar component.

In order to evaluate the total soluble solids content of citrus juices with the refractometer, Stevens and Baier *(11)* prepared a correction table for varying quantities of citric acid. McRoberts *(8)* also obtained satisfactory results in estimating solids by the refractometer in fruit products when corrections for the organic acid content were applied. He was principally interested in citrus products. McCara *(6)* developed tables which provided for correction factors for citric acid, glucose solids, and invert sugars in jams.

EXPERIMENTAL

Preparation of tartaric acid solutions. The solutions were prepared by dissolving appropriate weights of the anhydrous acid in freshly boiled distilled water. Concentrations were checked by titration in triplicate with standard N/10 NaOH with phenolphthalein as indicator.

Standardization of instruments. The Zeiss refractometer which was used in this study was checked against distilled water at 20° C. and also against the prism submitted by the instrument maker for this purpose. Both values indicated that the refractometer was properly adjusted.

The Brix hydrometer was checked against solutions of pure sucrose which had been previously dried at 100° C. for 6 hours before being used to prepare the sugar solutions. Concentrations of sucrose varying from 2.0 to 5.0% by weight were prepared by dissolving accurately weighed portions in appropriate weights of freshly boiled distilled water. Brix hydrometer readings taken at 20° C. indicated that the hydrometer had been calibrated accurately.

Refractometer and Brix readings of tartaric acid solutions. Refractometer readings of each tartaric acid solution were taken in duplicate at 20° C. The temperature was controlled by a flow of water from a constant temperature bath which was also used to maintain the cylinders of solution at 20° C. during the Brix readings. Duplicate Brix readings at each concentration of tartaric acid were also taken. The average value of both refractometer and Brix readings are listed in Table 1. The statistical treatment of this data involved the use of the equation for a straight line $y = a + bx$, where:

y = soluble solids (refractometer corrected)
a = intercept on y axis
b = slope of line
x = tartaric acid per cent by weight

The relationship of per cent tartaric acid to soluble solids as determined by the refractometer is illustrated in Figure 1. An almost linear relationship is indicated. When the data are referred to the method of least squares, the following values were obtained:

$a = 0.1264$
$b = 0.8863$

which result in the following equation: per cent soluble solids = 0.8863 × per cent tartaric acid + 0.1264. That the data do not contribute strict linear relationship is evidenced by the rather significant intercept, 0.1264, and also by the fact that the line does not pass exactly through the origin.

TABLE 1

Soluble solids of tartaric acid solutions as determined by the refractometer and Brix hydrometer

Tartaric acid per cent by wt. (titration value)	Refractometric values 20° C.		Brix hydrometer value 20° C.
	Sugar scale	Refractive index	
0.53	0.60	1.3338	0.60
1.01	1.00	1.3344	1.20
1.53	1.40	1.3350	1.82
2.02	2.00	1.3359	2.40
2.51	2.40	1.3365	3.00
2.99	2.80	1.3370	3.60
3.48	3.20	1.3376	4.00
3.97	3.60	1.3382	4.75

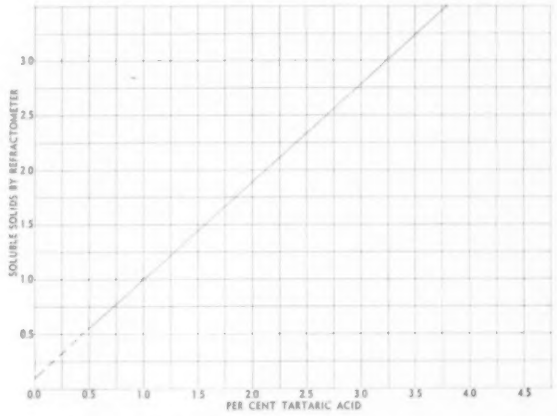

Figure 1. Relationship of soluble solids by refractometer to tartaric acid concentration.

The relationship of per cent soluble solids, determined by the Brix hydrometer, to per cent tartaric acid is shown in Figure 2. The data give rise to the following linear relationship: per cent soluble solids = 1.1739 × per cent tartaric acid + 0.0103. In this equation the intercept is almost zero and more adherence to absolute linearity is indicated.

Application of the two equations furnished the correction data listed in Table 2. Several examples may be informative. For instance, at the tartaric acid level of 2.0%, as determined by titration, the soluble solids given by the refractometer would be $(2 \times 0.8863) + 0.1264$ or 1.90%. A correction of +0.10%, as listed in the table, would be necessary to correct the value obtained by the refractometer to the true tartaric

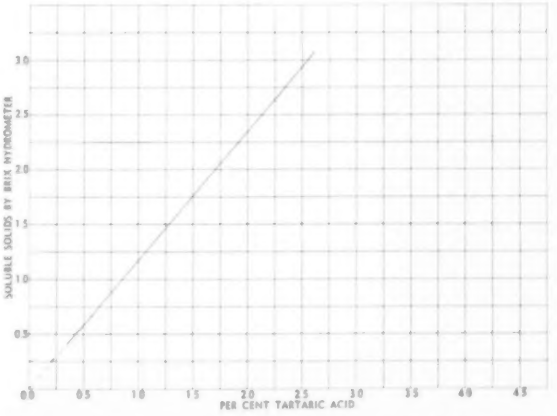

Figure 2. Relationship of soluble solids by Brix hydrometer to tartaric acid concentration.

acid soluble solid content. Similarly, at the 2.0% tartaric acid level, the Brix value would be $(2 \times 1.1739) + 0.0103$ or 2.35%. A negative correction of 0.36%, as shown in the table, is therefore necessary.

Data in Table 2 indicate that the Brix correction values increase steadily as the concentration of tartaric acid increases. Negative refractometric corrections must be applied when concentrations of tartaric acid up to 1.1% are measured. Concentration greater than 1.1% tartaric acid require positive corrections to the refractometric value in order to obtain the correct soluble solids values. (This is also proof that the over-all regression line obtained from the data does not obey strict linearity.)

TABLE 2

Tartaric acid correction table

A tartaric acid per cent by weight (titration value)	Values to be applied to soluble solids by refractometer	Value to be subtracted from Brix soluble solids
0.6	−0.06	0.11
0.8	−0.04	0.15
1.0	−0.01	0.18
1.2	+0.01	0.22
1.4	+0.03	0.25
1.6	+0.06	0.29
1.8	+0.08	0.32
2.0	+0.10	0.36
2.2	+0.12	0.39
2.4	+0.16	0.43
2.6	+0.17	0.46
2.8	+0.19	0.50
3.0	+0.21	0.53
3.2	+0.24	0.55
3.4	+0.26	0.60
3.6	+0.28	0.64
3.8	+0.31	0.67
4.0	+0.33	0.70
4.2	+0.35	0.73
4.4	+0.37	0.77
4.6	+0.40	0.81
4.8	+0.42	0.84
5.0	+0.44	0.88
5.2	+0.47	0.91
5.4	+0.49	0.95
5.6	+0.51	0.98
5.8	+0.53	1.02

Examination of mixtures of sucrose and tartaric acid. Two stock solutions of sucrose were prepared at the 15.0 and 55.0% levels by dissolving the appropriate weight of dried sucrose in freshly boiled distilled water. Refractometric readings indicated the soluble solids to be 15.1 and 55.2% respectively.

Two stock solutions of tartaric acid by weight were prepared, 12.5 and 25.0%. Titration with alkali in duplicate indicated the following concentrations of tartaric acid, 12.38 and 24.78%, respectively.

Four mixtures of sucrose and tartaric acid were prepared.

(1) 100.0 g. of 55.2% sucrose solution was carefully mixed with 20.0 g. of 24.78% tartaric acid. The resulting concentration of sucrose and tartaric acid should be 46.00% and 4.13%, respectively; and the total soluble solids should amount to 50.13%.

(2) 100.0 g. of 15.1% sucrose was mixed with 20.0 g. of 24.78 % tartaric acid. The resulting solution should contain 12.58 % sucrose and 4.13% acid and total solids content of 16.71%.

(3) 100.0 g. of 55.2% sucrose was mixed with 20.0 g. of 12.38% tartaric acid. This solution should contain 48.06% total solids, 46.00% sucrose, and 2.06% tartaric acid.

(4) 100.0 g. of 15.1% sucrose was mixed with 20.0 g. of 12.38% tartaric acid. This solution should contain 14.64% total solids, 12.50% sucrose, and 2.06% tartaric acid.

Total solids of all four solutions were obtained by the refractometer, the Brix hydrometer and also by the official vacuum oven drying method *(9)*. The results are given in Table 3.

TABLE 3

Soluble solids of mixtures of sucrose and tartaric acid per cent solids

Theoretical	Refractometer (uncorrected)	Refractometer (corrected)	Brix reading (uncorrected)	Brix reading (corrected)	Oven drying method
50.13	49.80	50.14	50.85	50.14	51.24
16.71	16.40	16.74	17.40	16.69	16.78
48.06	47.95	48.06	48.40	48.03	49.53
14.64	14.50	14.61	15.00	14.63	14.92

Soluble solids of malic acid solutions by refractometer. Little attention has been given by chemists to the presence and influence of malic acid. Hartman and Hillig *(5)* found 0.31% malic acid in a sample of grape juice which contained 1.07% tartaric acid. Wilson *(12)* found 0.40% malic acid in a grape juice which contained a total of 1.00% acid. From these meager data, malic acid would appear to be present as approximately 20 to 40% of the total acidity.

Six concentrations by weight of malic acid were prepared varying from 0.5% to 3.5%. The concentrations were verified by titration with standard alkali. These data along with the soluble solids expressed as sucrose are listed in Table 4. A graph showing the relationship between malic acid concentration by weight and the corresponding soluble solids as sucrose is illustrated in Figure 3. The linear relationship is expressed by the equation: soluble solids by refractometer = 0.9291 × per cent malic acid − 0.797. It will be observed that again the soluble solids read less than the acid concentrations. A positive correction is therefore again necessary when referring the refractometer value to the actual acid content by weight. Unfortunately, not enough pure malic acid was available to furnish solutions for Brix determinations.

TABLE 4

Soluble solids of malic acid solutions as determined by the refractometer

Malic acid per cent by weight (by titration)	Refractometric values 20° C.	
	Sugar scale	Refractive index
0.49	0.40	1.3335
0.99	0.80	1.3341
1.53	1.40	1.3350
2.03	1.75	1.3354
2.50	2.20	1.3362
2.92	2.70	1.3368
3.54	3.20	1.3376

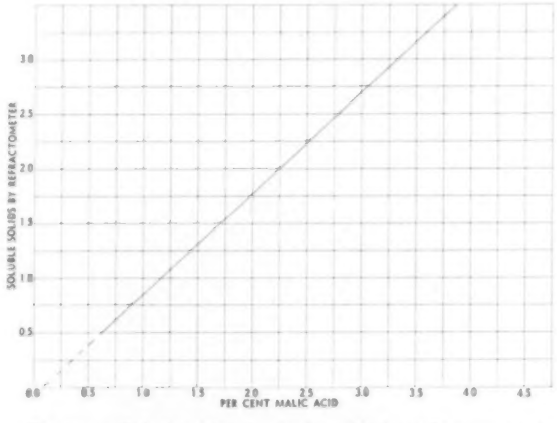

Figure 3. Relationship of soluble solids by refractometer to malic acid concentration.

Analysis of commercial samples of Concord grape concentrate. A total of 8 commercial preparations were examined. In determining total solids by the official method, 1.5 g. samples were intimately mixed with sand in an aluminum dish of 90 mm. diameter. Total acidity, expressed as per cent tartaric acid, was determined by potentiometric titration of exactly 5 g. with standard alkali. A potentiometric titration was employed because the natural coloring matter hinders visual inspection of the phenolphthalein end point. Refractometer and Brix readings were taken in the conventional manner. Data are listed in Table 5.

TABLE 5

Commercial frozen concentrated Concord grape juice (per cent by weight)

Sample	Acid as tartaric	Solids refract	Solids Brix	Solids refract corr.	Solids Brix corr.	Total solids vacuum oven
1	1.41	46.40	46.00	46.43	45.75	46.23
2	1.45	49.60	47.60	49.63	47.35	49.55
3*	2.32	49.80	55.20	49.93	54.80	50.51
4*	2.24	48.10	52.10	48.22	51.71	48.23
5	1.46	49.60	48.50	49.63	48.25	49.49
6	1.46	47.60	46.50	47.63	46.25	46.75
7	1.52	48.40	47.10	48.45	46.84	49.19
8	1.20	47.20	47.21	47.21		47.88

* These samples were of such jelly-like consistency that Brix readings were difficult to obtain.

DISCUSSION

Data in Table 3 indicate that for solutions containing only sucrose and tartaric acid, both refractometer and Brix hydrometer yield values which agree closely with the total theoretical solid content when the proper corrections are applied.

When the methods are applied to commercial preparations of grape concentrate, this agreement is not obtained. Inspection of Table 5 leads one to the conclusion that soluble solids values obtained by the refractometer are probably more reliable than those obtained by the Brix hydrometer. The average deviation of the per cent soluble solids obtained by the refractometer from the values given by the oven drying is $\pm 0.41\%$, ranging from 0.01 to 0.88%. In contrast, the average variation of the Brix results from those obtained by the new method is $\pm 2.22\%$, varying from 0.48 to 4.29%.

A reason frequently given for the lack of agreement between the methods is that inversion of sucrose by the tartaric acid occurs during the heating period. If all the sucrose were inverted during this procedure a 5% increase of weight would be contributed by the amount of sucrose inverted. If this were the true reason, the results by the oven drying method should be consistently higher than those obtained by the other two measurements. Inspection of Table 5 shows that of the 8 values obtained by the refractometer, four were higher than those obtained from the same samples by the drying method. The data also shows that two Brix values were considerably higher than the results obtained by drying. Also, the data in Table 3 show that although the results obtained by the oven drying method are consistently higher than the values obtained by the refractometer and the Brix hydrometer, indicating hydrolysis of sucrose during the heating period, this increase is considerably less than 5%. In other words, complete inversion does not occur even over a 6-hour period over 70°.

The following reasons are offered for the lack of agreement. Both the refractometer and the Brix hydrometer measure soluble solids; the oven drying method evaluates total solids, both soluble and insoluble. Because of the viscous consistency of grape concentrate, removal of water at 70° under vacuum for 6 hours may not always be complete.

The reason for the marked lack of agreement between the results obtained by Brix hydrometer and the oven drying method is probably a mechanical one. Because of the pectin present in grape concentrate, the product is necessarily of high viscosity, a condition which does not lead to hydrometer evaluation of high accuracy.

The Zeiss refractometer necessarily evaluates all refractometric readings in terms of sucrose. However, in grape juice most of the sugars are present as invert sugar. The following table indicates that soluble solids determined by the refractometer do not differ too markedly whether expressed as sucrose, invert sugar, or glucose.

TABLE 6

Soluble solids expressed as sucrose, invert, and glucose by refractometer

Sucrose per cent	Index of refraction	Invert sugar per cent	Glucose per cent
5.0	1.3403	5.02	5.06
10.0	1.3478	10.05	10.06
15.0	1.3557	15.10	15.18
20.0	1.3638	20.17	20.26
30.0	1.3811	30.35	30.40
40.0	1.3997	40.60	40.55
50.0	1.4200	50.85	50.85

The sucrose values were selected arbitrarily; the corresponding refractive values are listed in *A.O.A.C. Methods of Analysis*, p. 888, (loc cit). The equivalent invert sugar and glucose values were calculated by extrapolation to the nearest index of refraction.

These data indicate that soluble solids referred to the same index of refraction do not differ seriously whether expressed as invert or glucose. Since most of the sugar content of grape juice is invert sugar, the difference is of no consequence in applying a corrective factor. At the level of 15%, the concentration of invert in grape juice, a correction of 0.1% would need to be added to the soluble solids determined by the refractometer. Similarly, at a concentration of 30% invert, the concentration of invert in grape concentrate, the data listed in the table would indicate the need of applying a factor of 0.35% correction to the solids obtained by the refractometer. However, if this correction is applied to the results of the analyses of the 8 commercial grape juice concentrates, agreement between the values obtained by

the refractometer and the official oven drying method would not be improved. The average variation would become ±0.50%, ranging from 0.32 and 1.23% instead of the lesser values previously reported.

Consideration was given to the soluble solids contributed by malic acid. While the soluble solids correction value as determined by the refractometer is somewhat greater for malic acid than for tartaric acid, it would not be practicable to apply a specific malic acid correction factor because the amount of this acid in grape juice varies. Moreover, since the ratio of malic acid to tartaric acid is only in the order of 0.2–0.4, the added corrective factor required by the malic acid would hardly be significant.

Other constituents of grape juice that may affect the refractive index and Brix hydrometer readings are amino acids and dissolved mineral salts (i.e. K, Na, and Mg). Investigations should be conducted to ascertain whether or not these components enhance or depress the instrumental readings of the soluble solids. The effect of malic acid on the Brix hydrometer readings and refractometric readings should be studied further.

SUMMARY

Regression curves relating soluble solids, as sucrose, determined refractometrically to per cent by weight of tartaric and malic acid have been developed. These relationships are a new contribution.

A regression curve relating soluble solids, as sucrose, determined by the Brix hydrometer, to per cent by weight of tartaric acid has also been developed.

When the soluble solids of a tartaric acid sugar solution are evaluated by the refractometer, a positive correction is required. The amount increases with increasing tartaric acid concentrations.

A negative correction value must be applied when the soluble solids are obtained by the Brix hydrometer. The degree of correction also increases with increasing tartaric acid concentration.

When the corrections are applied, both methods of evaluating total soluble solids of synthetic mixtures of tartaric acid and sucrose yield values agreeing very closely with the amounts present.

When the methods are applied to grape juice concentrate, the values obtained by the refractometer are much closer in agreement with the solids obtained by the official oven-drying procedure than are the Brix values.

The average variation of soluble solid content of grape concentrate determined by the Brix method from the values obtained by the official drying method are five times the corresponding average variation given by the refractometer.

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Viscosity of Concentrated Orange and Grapefruit Juices[a,b]

(Manuscript received May 31, 1958)

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INFORMATION PUBLISHED in the literature concerning the viscosity of citrus juices is scant, and references to the viscosity of frozen and other concentrates prepared from citrus juices are also very limited. Investigations reported consist of viscosity determinations using extracted orange juices *(5, 15)*, citrus molasses *(7, 9)*, pasteurized orange concentrates *(8)*, and frozen orange and grapefruit concentrates *(2, 3, 4, 10, 11, 12, 18)*.

Viscosity can become an important factor during the concentration of citrus juices, especially in the production of high density concentrates, due to the inefficiency of the operation when the product becomes highly viscous. Then, too, a very viscous concentrate does not reconstitute easily; thus viscosity of the product is of practical importance to the consumer. Also it is possible that this characteristic might be an indication of the physical stability of the concentrate, which is an important quality factor. For these reasons, a need for further knowledge about the viscosity of citrus concentrates, as well as reliable and standardized procedures for measuring this characteristic, prompted this study.

EXPERIMENTAL PROCEDURE

Experimental and commerical samples. Experimental samples of orange concentrates used in this investigation were processed in the Station pilot plant. Juices were extracted using a Food Machinery In-Line extractor, finished through a Model 35 Food Machinery finisher, and the juices were then concentrated in the pilot plant evaporator *(1)*. Stabilization of the juices was accomplished by using a Walker Wallace heat exchanger prior to concentration. Cutback juice was added to concentrates from the evaporator to prepare some of the 42° Brix products. All products were packed in 6 oz. cans and stored at −8° F. until used for the viscosity determination, except when measurements were made on concentrates immediately after withdrawal from the evaporator.

The 100 commercial samples of 42° Brix frozen orange concentrate used in this study were collected from 24 Florida plants throughout the 1956–57 citrus season; 27 commercial frozen grapefruit concentrates were obtained from 10 Florida plants during the 1955–56 season. All of the commercial samples were stored at −8° F. until used.

Determination of viscosity with a Brookfield viscometer. If frozen, samples were removed from −8° F. storage and immersed in a 30° C. (86° F.) water bath for 90 minutes. At the end of this period the concentrate in a 6 oz. can had reached bath temperature. The can was then opened and replaced in the constant temperature bath. A Brookfield Model LVF synchroelectric rotational viscometer, with guard attached, was used. In nearly all cases the No. 2 spindle was used; however, for some measurements either the No. 3 or the No. 4 spindle was necessary. All measurements were carried out at 12 r.p.m., except for one experiment designed to show the effect of varying rates of shear on the viscosity. The scale reading was taken exactly 1 minute after turning on the Brookfield instrument, i.e. after 12 revolutions of the spindle; viscosity was expressed in centipoises as determined from the Brookfield scale reading by multiplying it by a conversion factor.

Determination of relative viscosity with pipette. The pipette used was a 200 ml. (Exax-TD 200) volumetric pipette which was modified by cutting off 2 cm. from the delivery end. This was done as citrus concentrates contain pulp particles which may become lodged in the small opening of the pipette and prevent the sample from flowing out freely. A calibration mark was made on the pipette so that the volume from this mark to the end of the pipette was 150 ml. As soon as the viscosity of a sample had been measured on the Brookfield viscometer, contents of the can were drawn up into the pipette. The time required for the 150 ml. to flow out was measured with a stopwatch. This time of flow for a constant volume is related to viscosity and, therefore, is indicative of this characteristic of a fluid. Following each determination the pipette was thoroughly rinsed with water and completely dried before another sample was tested.

Pulp content and centrifuged material. The pulp content of the citrus concentrates, after reconstituting to 12° Brix, was determined by a centrifugal method *(16)*; also, following storage of the concentrates, the centrifuged material was determined on the reconstituted products, using this same procedure.

Degree of clarification. A Photovolt Lumetron colorimeter, Model No. 402-E, with a 730 mμ filter and a 10 mm. rectangular 14 ml. cell, was used to determine the cloud or turbidity of the centrifuged reconstituted juices, both initally and after storage.

Statistical analysis. The correlation coefficient was calculated *(14)* using viscosity data obtained with both the Brookfield viscometer and the pipette, when 100 samples of commercial frozen orange concentrates were examined.

RESULTS AND DISCUSSION

Methods for determining viscosity. Viscosity is the measure of the internal friction of a fluid or the ease with which it flows. A liquid may be classified as either "Newtonian" or "non-Newtonian" depending upon the effect of the rate of shear on its viscosity. If the viscosity of a fluid is independent of the rate of shear, as with water, then it is called "Newtonian," whereas if a changing rate of shear results in a changing viscosity, then the fluid is "non-Newtonian." Some non-Newtonian liquids are further defined as being "thixotropic," in that a decrease in viscosity will result in such a product when it is subjected to constant shearing. Green *(6)* discusses in detail the complex subject of rheology, or the study of flow.

Citrus concentrates are non-Newtonian liquids having thixotropic properties and, therefore, possess a structure which breaks down upon shearing. This breakdown in structure may be temporary and, if shearing is stopped, the structure will rebuild and be accompanied by an increase in viscosity. This is illustrated by the data in Figure 2, which show that

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[b] Presented at the Eighteenth Annual Meeting of the Institute of Food Technologists, Chicago, Ill., May 27, 1958.

the viscosity of an orange concentrate decreased as the rate of shear was increased from 6 to 60 r.p.m.; also, data in Table 4 show that the viscosity of a 67° Brix orange concentrate increased after withdrawal from the evaporator from 3600 to 5130 cp., when it was stored for 4 hours at 80° F. Thus, the viscosity of a citrus concentrate when measured is only an "apparent" viscosity, which is useful as a comparative measurement only when determined under specific conditions. Such conditions must include the temperature, type of instrument and its accessories used, the rate of shear, and treatment of sample prior to the determination of its viscosity.

Data in Figure 1 indicate the importance of temperature control in determining the viscosity of citrus concentrates. The viscosities of the 4 commercial samples of 42° Brix frozen orange concentrate decreased as the temperature was increased, and it is evident that viscosity is a logarithmic function of the temperature. Most of the measurements of viscosity made during this study were at 30° C. ± 1°.

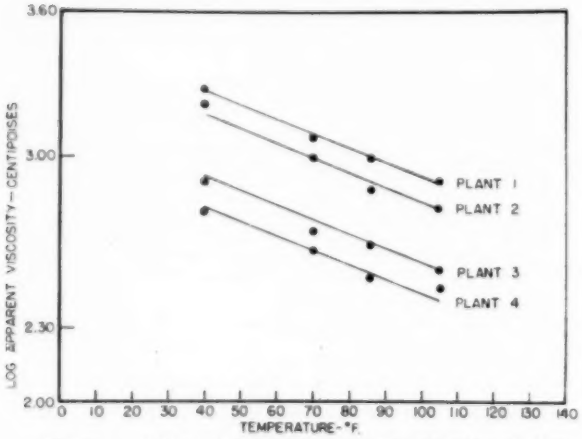

Figure 1. Effect of temperature on the viscosity of four commercial samples of frozen concentrated orange juice.

Another important factor to consider in measuring viscosity is rate of shear. The Brookfield LVF viscometer, used in this investigation, is capable of operating at 4 rates of shear, i.e. at 6, 12, 30, or 60 r.p.m. The effect of these different rates of shear was measured using 4 identical cans of 42° Brix Valencia orange concentrate and (Figure 2) the viscosity of the product decreased with increasing rate of shear. Thus, it is apparent that to obtain comparable viscosities, measurement must be made at a constant rate of shear and, therefore, a spindle speed of 12 r.p.m. was chosen for this study as it provided an adequate range of viscosities.

Data in Table 1 illustrate that orange concentrate, being thixotropic in nature, shows a decrease in viscosity with time under a constant rate of shear. As this breakdown ocurs, it is accompanied by a simultaneous buildup of the structure that is being broken down *(6)*. The viscosity continues to decrease with time until the rate of buildup equals the rate

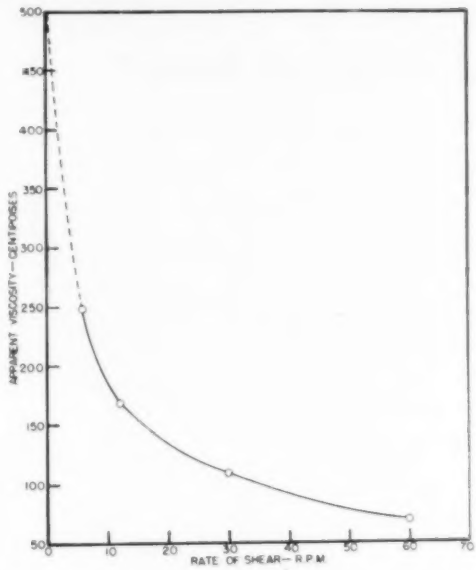

Figure 2. Effect of rate of shear on the viscosity of frozen concentrated orange juice.

of breakdown; then the viscosity is constant with time as long as the shearing rate is constant. For this reason all determinations were made exactly 1 minute after the shearing was begun, so that each sample would have undergone a similar period of breakdown.

The Brookfield LVF viscometer can be used with any one of a set of 4 spindles, which make it possible to measure a wide range of viscosities. At a rate of shear of 12 r.p.m., spindles No. 1, 2, 3 and 4 are recommended by the manufacturer to be used for maximum viscosities of 500, 2500, 10,000 and 50,000 cp., respectively, so that a maximum portion of the scale may be used resulting in greater accuracy. When 4 samples of Pineapple orange concentrate were examined using 3 different spindles, the results (Table 2) indicate that identical readings may or may not be obtained, with larger differences occurring with the products that had the higher viscosities. The No. 2 spindle was usually used during this study and it is believed that measurement of the viscosities likely to be found in either 42° Brix concentrates or those of higher density may be measured satisfactorily using either No. 2 or 3 spindles.

TABLE 1

Change in viscosity with time of 42° Brix Pineapple orange concentrates, when under constant rate of shear

Time in minutes	Apparent viscosity in centipoises [1]			
	Sample 1	Sample 2	Sample 3	Sample 4
1	400	470	605	1240
2	385	460	590	1200
3	375	450	580	1190
4	370	445	575	1180
5	370	445	570	1170

[1] Measured at 30° C. (86° F.) with No. 2 spindle, Brookfield LVF viscometer at 12 r.p.m.

TABLE 2

Measurement of viscosity of Pineapple orange concentrates using different Brookfield spindles

Spindle number	Apparent viscosity in centipoises [1]			
	Sample 5 42° Brix	Sample 6 42° Brix	Sample 7 56° Brix	Sample 8 52° Brix
2	805	1205	Off scale	Off scale
3	800	1250	3160	5980
4	800	1500	3500	6600

[1] Measured at 30° C. (86° F.) with Brookfield LVF viscometer at 12 r.p.m. after 1 minute.

Viscosity of commercial frozen concentrated orange juice. The frequency distribution of viscosity data obtained from the examination of 100 samples of commercial frozen orange concentrate is shown in Table 3; apparent viscosity was determined using the Brookfield LVF viscometer and relative viscosity was obtained with the use of a pipette. The results show that the samples from the midseason packs were more viscous than those from the late season packs. The frequency distribution of the samples according to their viscosity also show 69% of the samples falling under 1000 cp., with approximately one-half of this number below 750 cp. Only 10% of the samples were above 1500 cp. The minimum and maximum values were 430 and 2500 cp.

Statistical analysis of the viscosity data, obtained using both the Brookfield LVF viscometer and the pipette, resulted in a correlation coefficient of 0.967, indicating excellent correlation since 0.254 or higher is significant at the 1% level. Thus, the pipette method provides a simple, rapid, cheap, accurate procedure for determining the relative viscosity of citrus concentrates. This has been previously recognized and a similar procedure is used by the British Food Ministry for the measurement of the relative viscosity of concentrated orange juice.

TABLE 3

Frequency distribution of viscosities for 100 samples of commercial frozen concentrated orange juice obtained during the 1956–57 citrus season

Centipoises	Apparent viscosity [1]—Brookfield viscometer		Total packs
	Midseason packs [3]	Late season packs [3]	
	% of samples	*% of samples*	*% of samples*
0– 249	None	None	None
250– 499	None	7.1	3
500– 749	13.8	52.5	30
750– 999	43.0	26.2	36
1000–1249	19.0	11.8	16
1250–1499	6.9	2.4	5
1500–1749	3.5	None	2
1750–1999	6.9	None	4
2000–2249	3.5	None	2
2250–2499	1.7	None	1
2500–2749	1.7	None	1
Time in seconds	**Relative viscosity [2]—Pipette**		**Total packs**
	Midseason packs [3]	Late season packs [3]	
	% of samples	*% of samples*	*% of samples*
0– 14	None	4.8	2
15– 29	41.5	76.0	56
30– 44	34.4	16.8	27
45– 59	6.9	2.4	5
60– 74	8.6	None	5
75– 89	3.5	None	2
90–104	1.7	None	1
105–119	None	None	None
120–134	1.7	None	1
135–149	1.7	None	1

[1] Measured at 30° C. (86° F.) with No. 2 spindle, Brookfield LVF viscometer at 12 r.p.m. after 1 minute.

[2] Measured at 30° C. (86° F.) by time for flow of 150 ml. of concentrate from pipette.

[3] Fifty-eight midseason samples packed from December 1 to March 15, and 42 late season samples packed from March 15 to June 15.

Viscosity of commercial frozen concentrated grapefruit juices. Twenty-seven samples of commercial frozen grapefruit concentrate were collected from 10 Florida plants during the 1955–56 citrus season. The viscosities of these products, as measured with the Brookfield LVF viscometer, ranged from 150 to 1885 cp. and generally were not very viscous; 93% of the samples were below 1000 cp. and 67% were below 500 cp. Many of these samples contained added sugar.

Effect of degree of concentration and pulp content on viscosity of orange concentrate. As orange juice is concentrated by removal of water, one would expect the viscosity to increase accordingly. The effect of this increasing concentration on the viscosity is shown in Figure 3 for concentrates made from orange juices containing different amounts of pulp. It is apparent that as water is removed the viscosity increases in a gradual manner up to about 3-fold or 33° Brix and thereafter the rate of increase is much more rapid; this increase was as much as 300 cp. for a 1° rise in Brix value, with the concentrate containing 15.5% pulp. It is quite important then that any comparative viscosity measurements be made at the same degree of concentration or Brix value. The effect of the pulp content on both the viscosity and the rate of increase of viscosity with concentration is also evident from Figure 3. The concentrate containing 9.5% pulp had a lower viscosity at every concentration level than those with pulp content of 11.0, 13.0,

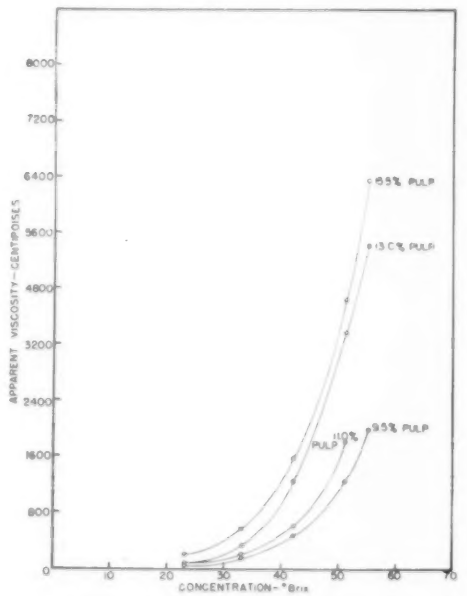

Figure 3. Effect of degree of concentration and pulp content on the viscosity of frozen concentrated orange juice.

and 15.5%; it also showed a somewhat less sharp increase in viscosity with concentration. These results are similar to those reported by DuBois and Murdock *(4)*.

Relation of viscosity to clarification of orange concentrate. It is believed that a relationship may exist between the viscosity of a citrus concentrate and its physical stability, i.e. its tendency to clarify or gel, since the amount of pulp and pectin in such products are factors that affect both physical stability and viscosity. A measurement of viscosity is relatively easy to make even though, as has been pointed out, very specific conditions must be established concerning the procedure. Therefore, perhaps the viscosity may be used as one characteristic of citrus concentrates for predicting the physical stability of such products before they are packed and frozen in cans. Some indication of this possibility was found in data obtained during this study.

TABLE 4

Change in viscosity of Valencia orange concentrate during concentration and storage at 80° F.

Approx. fold[2]	Brix value	Apparent viscosity in centipoises[1]				
		Initial	After 1 hr. at 80° F.	After 2 hr. at 80° F.	After 4 hr. at 80° F.	After 2 days at −8° F.
2	23.0	60	80	90	105	110
3	33.0	140	230	255	280	255
4	42.5	300	415	440	490	450
5	51.5	575	695	740	775	770
6[3]	59.0	1270	1580	1640	950[4]	1700
7[3]	67.0	3600	4560	4700	5130	4900

[1] Measured at 80° F. (26° C.) with No. 2 spindle, Brookfield LVF at 12 r.p.m. after 1 minute.
[2] Based on 12° Brix juice.
[3] Spindle No. 3 used.
[4] Questionable.

Results presented in Table 4 show the differences in viscosity of Valencia orange concentrates at various levels of concentration, as well as the change that occurred after these products were removed from the evaporator and then stored at 80° F. It should be noted that the viscosities of these concentrates increased during storage at 80° F. for 4 hours; also, that freezing and storage at −8° F. during a period of 2 days resulted in an increase in viscosity corresponding to a storage period between 2 and 4 hours at 80° F. Juice used for the preparation of these products was heated at 175° F. prior to concentration.

Clarification occurs in a citrus concentrate when the pectin in the product is demethylated by the pectic enzyme, pectinesterase, as reported by Wenzel, Moore, Rouse and Atkins *(17)*. Also, Rouse, Atkins and Moore *(13)* have shown that there is an increase in the centrifuged material in a reconstituted juice when clarification occurs, because of the precipitation and separation of insoluble pectinates and pectates. Differences in viscosity, degree of clarification, and centrifuged material found in Valencia orange concentrates examined initially and after storage for 24 hours at 80° F. are reported in Table 5. No gelation occurred in any of these samples during storage. Definite clarification was found only in the 3 and 4-fold concentrates, and this was accompanied by large increases in viscosity of 268 and 200%. Folds 5, 6, and 7 which did not clarify had viscosity increases of only 62, 45, and 63%, respectfully; these increases may be attributed primarily to the normal thixotropic buildup. Therefore, the much greater increases in the 3 and 4-fold products must be attributed, in a large part, to changes taking place during the clarification process. It is believed that such changes in viscosity will be much larger in concentrates made from midseason fruit, such as the seeded Pineapple orange. Other research will be instigated to obtain more data concerning the relationship between viscosity and the physical stability of frozen citrus concentrates.

SUMMARY

Results show that citrus concentrates are non-Newtonian, thixotropic liquids. Therefore, it is stressed that procedures for measurement of viscosity of such products must be specified concerning temperature, instrument and accessories used, rate of shear, and treatment of sample prior to measurement.

The viscosities at 30° C. (86° F.) of commercial and experimental samples of citrus concentrates were determined using 2 procedures: (a) Brookfield LVF viscometer, usually with No. 2 spindle, at 12 r.p.m. after 1 minute, and (b) time of flow of 150 ml. from a pipette. A correlation coefficient of 0.927 was obtained by statistical analysis of viscosity data from the examination of 100 samples of commercial frozen concentrated orange juice.

TABLE 5

Relation of viscosity to the degree of clarification in Valencia orange concentrate

Approx. fold[3]	Brix value	Concentrate Apparent viscosity[1]			Reconstituted juice Degree of clarification[2]			Reconstituted juice Centrifuged material		
		Initial	After 24 hr. at 80° F.	Difference	Initial	After 24 hr. at 80° F.	Difference	Initial pulp	After 24 hr. at 80° F.	Difference
		cp.	*cp.*	%			%	*% by vol.*	*% by vol.*	%
2	23.0	60	Not uniform	.....	40—None	51—None	28	10.0	12.5	25
3	33.0	140	515	268	40—None	74—Definite	85	10.0	16.0	60
4	42.5	300	900	200	40—None	72—Definite	80	9.5	15.0	58
5	51.5	575	930	62	38—None	41—None	8	9.0	11.0	22
6[4]	59.0	1270	1840	45	37—None	38—None	3	8.5	10.5	24
7[4]	67.0	3600	5860	63	37—None	36—None	3	8.5	11.0	29

[1] Measured at 80° F. (26° C.) with No. 2 spindle, Brookfield LVF viscometer at 12 r.p.m. after 1 minute.
[2] Degree of clarification determined as percentage light transmittance of centrifuged reconstituted juice using Lumetron 402-E. Degree of clarification for orange juice: 0–59% = none; 60–69% = slight; 70–84% = definite; 85–100% = extreme.
[3] Based on 12° Brix juice.
[4] Spindle No. 3 used.

Concentrates produced while midseason fruit was available were more viscous than those packed commercially during the late season period. The viscosity of commercial frozen 42° Brix concentrated orange juices ranged from 430 to 2500 cp.; commercial frozen grapefruit concentrates from 150 to 1885 cp. Frequency distribution tables of the viscosity data for the orange concentrates are shown.

Data indicate that the viscosity of orange concentrate increases with the degree of concentration and the rate of increase is larger at higher concentrations. Also, concentrates prepared from citrus juices with high pulp content are more viscous than those made from juices containing smaller quantities of pulp.

The postulate that a relationship exists between the viscosity and the physical stability of citrus concentrates, such as the tendency for clarification to occur, is supported by some data from this investigation.

Acknowledgments

Thanks are extended to R. W. Olsen, under whose supervision all of the experimental packs used in this investigation were prepared; also, to W. F. Schopke for his aid in processing these products. The initiating ideas, which prompted this research, suggested by Dr. F. W. Wenzel and his discussions with the author concerning the nature of the problem were most helpful.

Appreciation is also expressed to all of the Florida companies that supplied the commercial samples of orange and grapefruit concentrates and to the personnel of the Agricultural Marketing Service, USDA, Winter Haven, Florida, for their help in obtaining these samples.

The author consulted with Mr. W. G. Mitchell, Pasco Packing Company, Dade City, Mr. Clarence W. DuBois, Minute Maid Corporation, Plymouth, Mr. Robert W. Kilburn, Florida Citrus Canners Cooperative, Lake Wales, and Mr. Ellis M. Byer, General Food Corporation, Florence Villa, concerning the measurement of the viscosity of citrus concentrates, and their suggestions are appreciated.

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Time-Temperature Tolerance of Frozen Foods. XV.

Method of Using Temperature Histories to Estimate Changes in Frozen Food Quality[a]

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(Manuscript received May 31, 1958)

OUR LABORATORY and others have in recent years collected extensive information on quality changes in frozen foods. These studies have been published in a number of papers, chiefly in this Journal *(1, 3, 4, 5, 6, 7, 8, 9, 14)*. Experimental conditions have included varying temperature levels and several different kinds of varied temperature patterns.

Data obtained in this time-temperature tolerance project (TTT), however, are not directly applicable to the estimation of quality changes in any given lot of frozen foods because of the wide and unpredictable variations in time-temperature experiences which occur during transportation and distribution. Different temperature histories produce different degrees of quality change, depending on the nature of the time-temperature pattern. Therefore, it would be desirable to develop a simple procedure which would give an estimation of the accumulated quality change in a product at any point in the distribution system no matter how variable or irregular the time-temperature pattern might be. This kind of information would indicate proper action for the protection of quality at any stage in the commercial life of a frozen food.

Since close agreement has been found between sensory methods and certain chemical and physical tests *(4, 5, 6)*, the most direct and straight-forward procedure for obtaining this quality information would involve sampling at various points and chemically or physically determining the constituents that are known to be correlated with quality. This procedure would require trained chemists or technologists and adequate laboratory facilities for the tests, some of which are time consuming. Furthermore, under commercial conditions it may not always be possible to make the required samplings and obtain laboratory information in time to be of use in determining proper action for protection of quality.

Although the TTT data are not directly applicable to estimation of accumulated changes under any given irregular time-temperature pattern, analysis of existing data reveals that rates of change at steady temperatures can be used as a basis for developing a quick and simple procedure which gives the accumulated change, provided the temperature history is recorded. This paper explains and illustrates such a procedure.

[a] Presented at the Eighteenth Annual Meeting of the Institute of Food Technologists, Chicago, May 27, 1958.

[b] Western Utilization Research and Development Division, Agricultural Research Service, U. S. Department of Agriculture.

DEVELOPMENT OF PROCEDURE

The total amount of change in a characteristic of a frozen food, as a result of its subjection to a known temperature history, can usually be estimated with satisfactory precision if adequate measurements have been made of the rates of change of that characteristic in similar samples at a number of different steady temperatures within the temperature range in question. Limitations on this possibility are discussed later.

The procedure for the estimate is self-evident if the temperature history consists simply of a number of constant-temperature phases, at each of which the rate of change is known. In practice, of course, such a simple history will never be encountered, because the temperature of the food in a package or case only gradually approaches equilibrium with the temperature of its surroundings after the latter has been suddenly changed. Even under a continuously variable temperature a satisfactory estimate of total accumulated change might be made with interpolated rates of change in each of many very short intervals. Attempts to develop a more general procedure led to an adaptation of a graphical method proposed by Schultz and Olson *(16)* for estimating required processing time in food canning.

The first step in the procedure is to derive from the experimental data a smooth curve expressing the relationship between temperature and the relative rate of change of the characteristic in question.

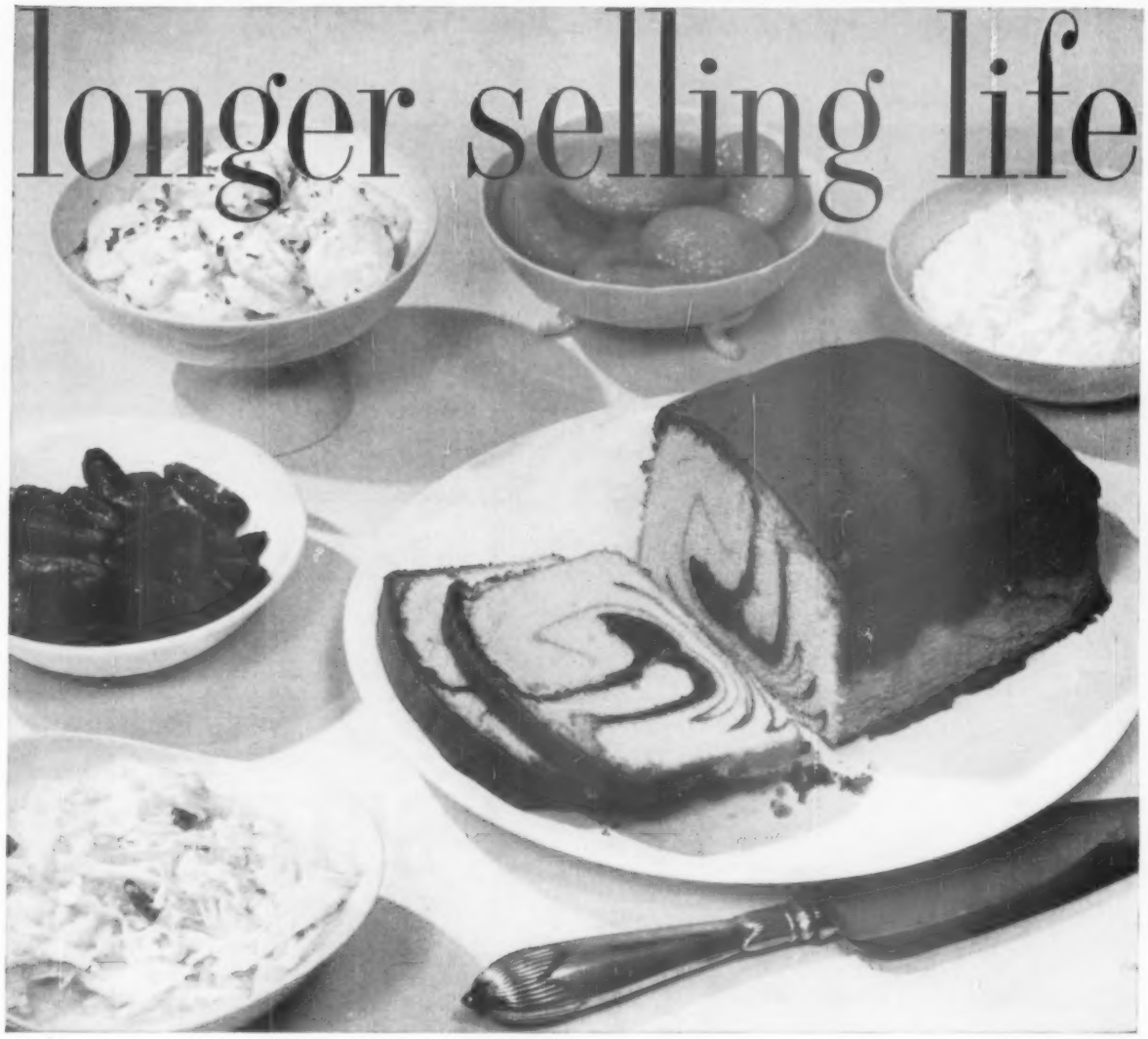
In some cases the measured quantity may change linearly with time at a constant temperature (at least within the range we are primarily interested in, the high-quality range). Here the rate of change would be expressed in some such unit as milligram-per cent ascorbic acid per day. In other cases some simple function of the measured quantity may change linearly with time—for example, the logarithm—and we shall plot the slopes of these straight lines against the corresponding temperatures.

The nature of the function that will linearize curves of the measured quantity plotted against time, however, need not even be known. For example, suppose that some characteristic, Q, is measured at intervals in samples held at a number of different steady temperatures. Then the reciprocals of the times required to reach some chosen value of Q at the different temperatures are proportional to the mean rates of change of Q from its initial value. These mean rates of change will be plotted against the corresponding temperatures. It is usually more convenient, however, first to express each of these rates as a multiple of the rate at some reference temperature, for instance 0° F. This set of ratios should be determined at several different values of Q in the region of interest. The ratios must be substantially identical, whatever the value of Q, and a mean should be taken to smooth out any minor variation.

The condition that the ratios of rates shall be the same no matter what value of Q is chosen is necessary for mathematical correctness of the procedure. This is obviously true if the data for Q against time at constant temperature start from a common vertex, Q, at zero time, and either fall on straight lines or can be converted to straight lines by a uniform transformation (for example, plotting the logarithm of Q).

The next step in the graphical procedure is to construct a coordinate system in which uniformly spaced abscissae represent time and the ordinates are spaced in proportion to the rate of change of the measured quantity Q at successive integral values of temperature, as read from the curve of rate versus

longer selling life



Sorbic prevents spoilage, increases profits

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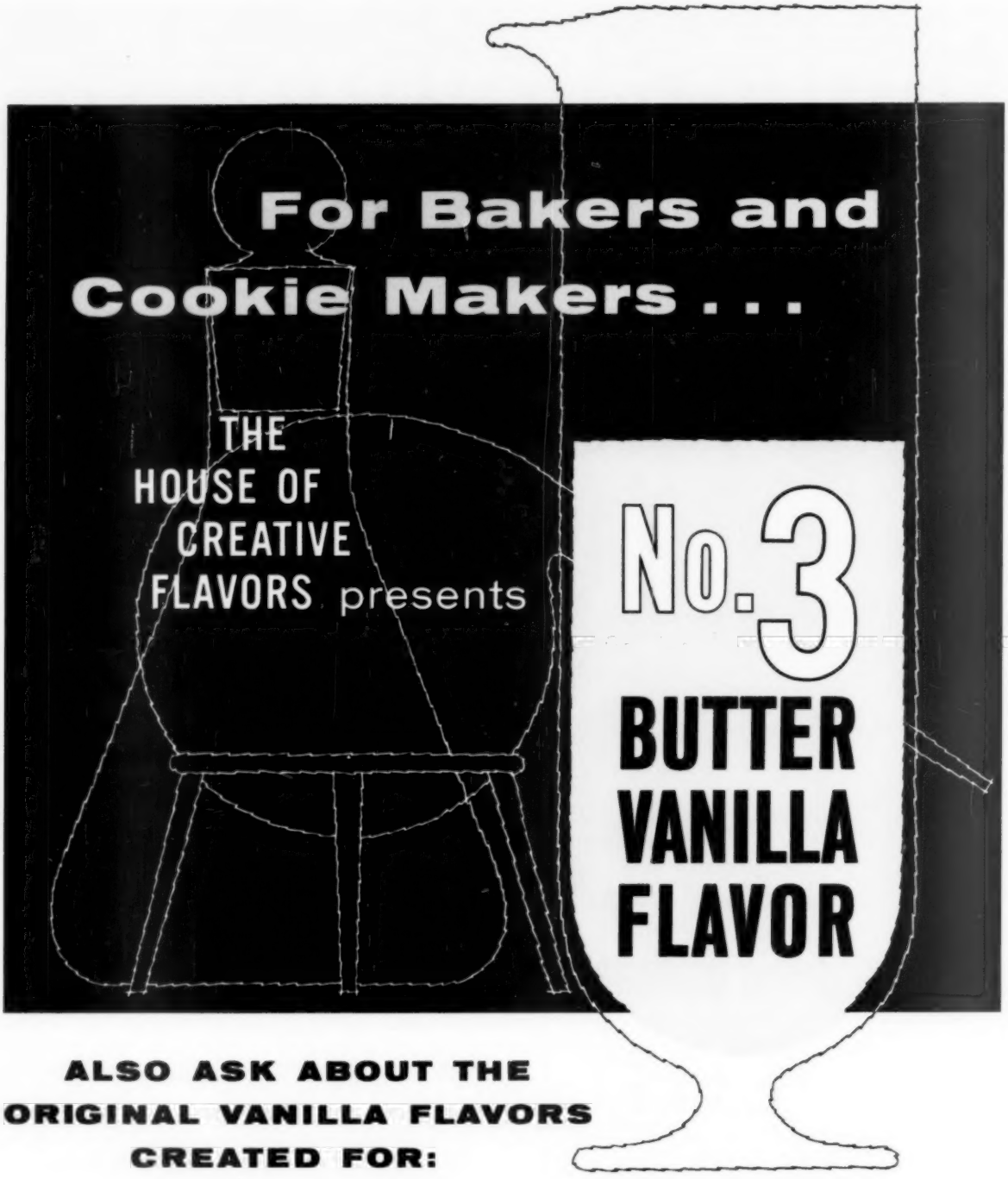

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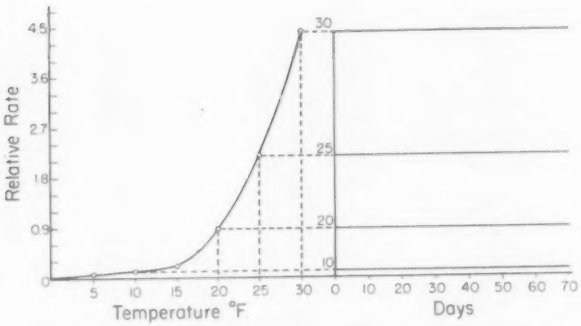

Figure 1. Construction of a transformed coordinate system from a plot of relative rate of change versus temperature.

temperature. This is most conveniently done as shown in Figure 1. Now the unequally spaced ordinates are labeled with the appropriate *temperatures*, instead of the rates of change from which they were derived.

The known irregular temperature history of a particular lot of frozen food is next plotted in this transformed coordinate system and the plotted points are connected by smooth curves. Now since the ordinates of this curve actually represent the instantaneous rate of change of the quantity Q and the abscissae represent time, the area beneath the curve is proportional to the total amount of change in Q.

In practice this area can either be measured with a planimeter, or the coordinate net can be constructed on a background of ordinary arithmetical cross-section paper in a contrasting color, and the area can be determined by counting the small squares in the background.

Consideration of the scale units now permits translation of the measured area under the curve either into an explicit total change in Q (provided the change was either linear with time or could be linearized by use of a known function) or at least into terms of equivalence with exposure of the sample to some chosen steady reference temperature. Equivalence to some exposure to a constant temperature can be expressed in either of two ways—either the length of time at some selected steady temperature, or the "effective" steady temperature which will produce the same total change in the same total length of time. The latter represents a generalization of the procedure described by Hicks *(10)* and by Schwimmer, Ingraham, and Hughes *(17)* for estimatitng the effect of a continuously fluctuating temperature.

The necessary arithmetic is straightforward. The area beneath the history curve on the transformed coordinates is to be equaled either by the area beneath a chosen horizontal reference temperature line, length of time being the variable to be computed, or by the area beneath an unknown horizontal temperature line, length of time being the same as in the actual history, and the height of the temperature line to be determined.

In general, two conditions are necessary and sufficient to assure the mathematical validity of the procedure that has been described. First, the change in the characteristic in question must be simply additive. Second, it must be commutative.

Simple additivity of changes that we measure or estimate in frozen foods cannot be assumed as self-evident. It must be demonstrated—at least, in a sufficient number of different kinds of system to give us confidence that we recognize and are within the limits of its validity. The long controversy about the importance of fluctuations of storage temperature illustrates the kind of question involved. If fluctuation *per se* produces more change than can be accounted for by the known rates and temperature coefficients, then the change is not simply additive. The reality of such an effect has been demonstrated by Klose, Pool, and Lineweaver *(13)* for the amount of frost formation under the wrappers of frozen turkeys. Other less well documented cases have been described *(2, 11, 12, 15, 19, 20, 21)*. As nearly as the authors can evaluate these reports, certain types of changes may be non-additive, but the changes most closely associated with quality deterioration have not shown such effects. This is in agreement with our own work on frozen fruits and vegetables *(1, 3)*.

Like additivity, commutativity cannot be assumed. It must be demonstrated. In this connection, commutativity pertains to the question of whether the final effect depends at all upon the *order* in which the various experiences are presented. The procedure we are describing will be valid only if the answer to this question is no.

In the planning of the comprehensive TTT investigations at this laboratory, tests of the commutativity of experiences were included for practically all of the commodities examined. These tests typically consisted of comparison of the total change in various objective analyses after samples had been subjected to two different temperatures, with time divided so that the higher-temperature part occurred either first, last, or between two lower-temperature parts. In none of these planned tests was any significant difference found.

We can easily prove that any system which exhibits constancy of ratio betwen times required to bring about the same amount of change at different temperatures is commutative. Thus this condition can be tested either by analysis of data showing changes as a function of time at several steady temperatures, or by setting up the special commuting experiments described in the preceding paragraph.

Use of the constancy-of-ratio criterion makes it possible to throw at least a narrow bridge across the deep chasm between the field of objective measurements on the one side and subjective judgments on the other. In the discussion up to this point we have been thinking primarily about the periodic measurement of the concentration of ascorbic acid or the percentage conversion of chlorophyll to pheophytin—measurements whose rate of change with time can be determined directly. We know, however, that the correlation between a large and very important class of deteriorative changes with any known set of chemical or physical changes has not been established satisfactorily; the onset of "rancid" or "stale" off-flavors is one of these.

The crucial fact is that the *very first* sure occurrence of off-flavor is the *end* of the only time period in which we are very much interested—the period during which the product is undeniably high quality. Until the end of that high-quality period, the members of the taste panel have been unable to show that they can distinguish the test sample from its control. There are no data to be plotted against time, and there is no way to tell what kind of function would fit the rates of the chemical changes that surely must have gone on, even though their effects were not yet perceptible to human senses.

However, the narrow bridge rests on these bases: We can determine experimentally whether the system fulfills the commutative condition and we can use the panel results to establish the mean rates at which the change occurs at different steady temperatures. If these things are given, the procedure we have described will enable us to estimate the effect of a variable temperature history, insofar as this exact kind of subjective evaluation is concerned. It will tell us nothing about the time of occurrence of some other kind of subjective end-point. We have not yet explored applicability of the procedure to our experimental data on this kind of system, but hope to be able to do so in the near future.

APPLICATION OF THE PROCEDURE

Figures 2 and 3 show a series of time-temperature patterns which were used to simulate various transportation and distribution conditions. The R_1 or transportation segment, of the pattern shown in Figure 2 was taken from an actual record of temperature changes in a carload of frozen foods during shipment across country. The patterns in Figure 3 are assumed conditions chosen to show the effect of temperature during transportation and distribution. Several lots of commercial samples of frozen fruits

and vegetables were subjected to the patterns in Figures 2 and 3, as well as at steady temperatures from 0° to 30° F. Plots of average rate of change versus temperature for these commodities are shown in Figures 4, 5, 6, and 7.

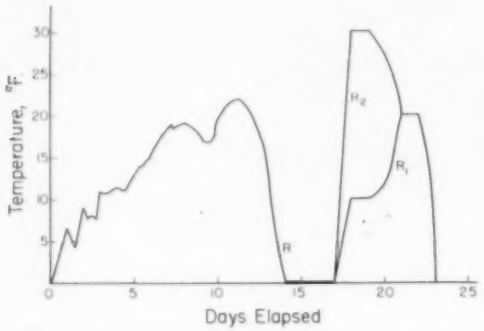

Figure 2. Temperature histories for raspberries, strawberries and peaches. R represents transportation and R_1 and R_2 refer to different distribution patterns.

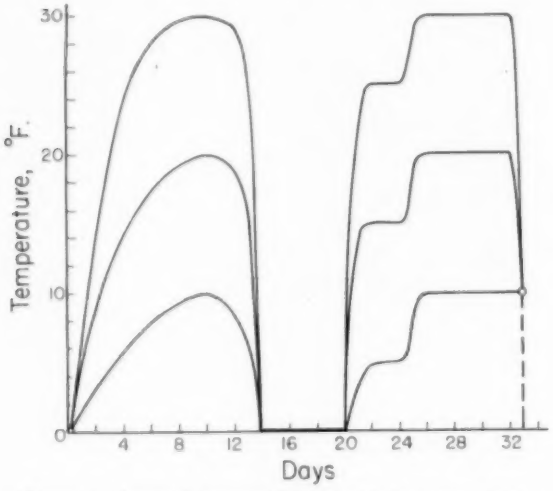

Figure 3. Assumed temperature histories for green beans.

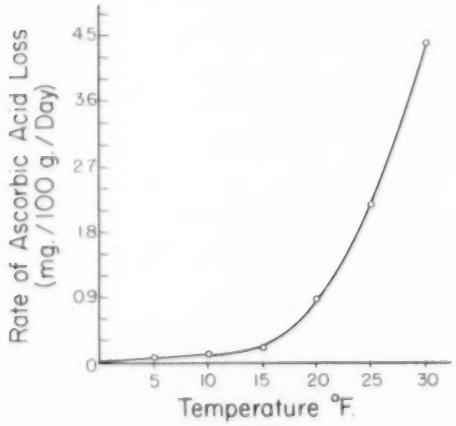

Figure 4. Average rate of ascorbic acid loss in frozen strawberries as a function of temperature.

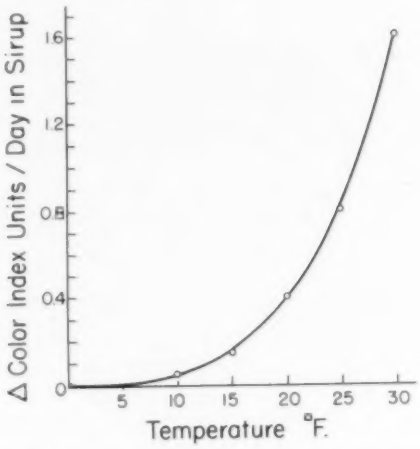

Figure 5. Average rate of change in raspberry sirup color as a function of temperature.

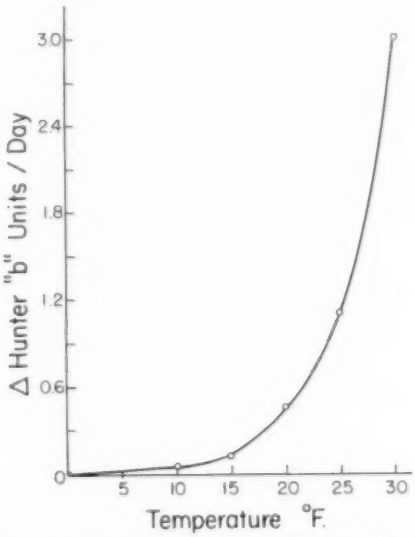

Figure 6. Average rate of change in surface color of peach slices as a function of temperature. Color measurements were made with a Hunter Color Difference Meter.

Table 1 shows the equivalency of various temperature patterns to days of storage at 20° F., as determined by rates of change in ascorbic acid and color. There is close agreement in equivalent number of days between the two sets of measurements. The fact that this agreement is not limited to a given product but applies to peaches, strawberries, and raspberries is a result of the fact that they have similar temperature coefficients of change. This does not mean that the rate at 20° F. is the same for the 3 fruits, but that the ratio of the rates at different temperatures is similar. Thus, if it is desired to determine the equivalent days at 20° F. or any other steady temperature experienced during shipment of a carload of frozen strawberries, raspberries, and peaches, it is only necessary to apply the rate-of-change data for *one*

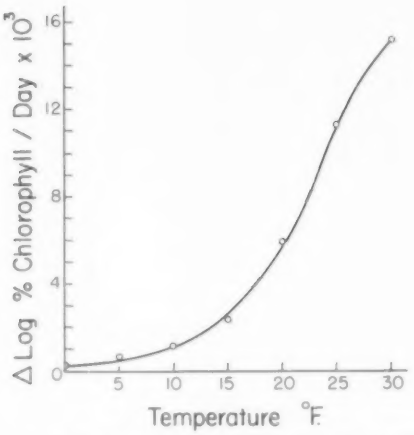

Figure 7. Rate of change in percent chlorophyll retention as a function of temperature.

test to *one* product; the resulting number will apply to other products in that car which have (a) the same temperature record, and (b) the same temperature coefficient of quality change. Obviously, different parts of the car will have different temperature records, which will change the equivalency by an amount depending on the difference in temperatures.

Next, let us compare predicted or calculated values for ascorbic-acid loss and color change based on the integration procedure with values actually found after the products experienced segments R, R + R_1, and R + R_2. The predicted values for the various distribution segments were calculated as follows: The rates of ascorbic acid loss and color change at steady temperatures for several lots of strawberries (36 lots), raspberries (16 lots), and peaches (10 lots) were averaged. The mean value plus and minus two times the standard deviation was then considered the range of rates encountered for that particular commodity. Thus, approximately 95% of the lots would fall within this range of rates.

Figure 8 shows both maximum and minimum rates corresponding to any given temperature plotted on the transformed coordinate scale derived from the rate-vs.-steady temperature plot shown in Figure 4. The equivalent number of days at 20° F. for each of these curves for each distribution segment was then multiplied by the average rate at 20° F., and these figures represent the calculated range of ascorbic acid loss or color change for each of the distribution segments.

Data for all the products and temperature experiences shown in Table 2 were calculated in this manner. The average actual values reported for peaches, raspberries, and strawberries are all well within the range of calculated values for all three segments of the distribution pattern and for both ascorbic acid loss and color change. Thus experimental data agree

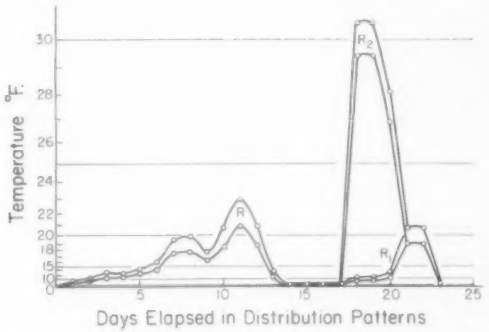

Figure 8. Transportation and distribution patterns plotted on transformed coordinates constructed from data on ascorbic acid loss in strawberries. The two curves represent maximum and minimum rates for 95% of the lots tested.

TABLE 2

Comparison of calculated and actual values of various factors in frozen strawberries, raspberries, and peaches as affected by temperature experience

Raspberries

Temperature experience	Ascorbic acid loss mg./100 g.		Color index units in sirup	
	Calculated[1]	Found[2]	Calculated[1]	Found[2]
R	1.0–1.2	1.1	2.1–2.8	2.3
R + R_1	1.4–1.8	1.6	3.0–4.0	3.4
R + R_2	2.8–3.6	3.3	6.0–8.0	6.8

Peaches

Temperature experience	Ascorbic acid loss mg./100 ml.[3]		Hunter "b" units	
	Calculated[1]	Found[2]	Calculated[1]	Found[2]
R	8–12	10	2.0– 2.6	2.1
R + R_1	14–19	16	2.8– 3.6	3.0
R + R_2	26–32	30	9.0–10.0	9.4

Strawberries

Temperature experience	Ascorbic acid loss mg./100 g.		Hunter "a" units	
	Calculated[1]	Found[2]	Calculated[1]	Found[2]
R	5– 8	6.9	1.2–1.6	1.5
R + R_1	7–11	9.0	1.6–2.4	2.1
R + R_2	18–23	21.1	4.0–5.2	4.8

[1] 95% of the lots tested fall within the range of values shown.
[2] Average of several typical lots.
[3] mg./100 ml. drained sirup.

TABLE 1

Comparison of various measurements for estimating equivalency of certain temperature experiences to days of storage at 20° F.

Temperature[1] experience	Raspberries		Strawberries		Peaches	
	Ascorbic acid loss	Color index	Ascorbic acid loss	Δ Hunter "a" value	Ascorbic acid loss	Δ Hunter "b" units
R	7.2	7.0	7.1	6.9	6.8	6.5
R + R_1	10	9.5	10.0	10.7	9.8	8.9
R + R_2	21.3	20	23	21.6	24.3	26.0

[1] See Figure 2.

well with the values computed from the rate-of-change experiments by the graphical integration procedure. These data are particularly significant, because they were derived from a very irregular temperature pattern reproduced from an actual temperature record obtained during shipment of a carload of frozen foods (R).

HIGH-QUALITY LIFE

In connection with this graphical integration procedure, we believe it would be useful to express results obtained from irregular temperature patterns in terms of how much "high-quality" life remains after a given unfavorable temperature exposure. This requires some assumptions and definitions which are admittedly arbitrary but nevertheless useful in making relative comparisons of different time-temperature experiences.

During the TTT project we have accumulated extensive data on flavor and color changes at various steady temperatures. Using the triangle test and trained laboratory panels, we have repeatedly found that the original "high quality" was definitely lost when 70% of the judges correctly identified the duplicate samples. By loss of "high quality," we mean loss of natural fresh flavor or desirable color and appearance in the thawed product.

It is recognized that this degree of change may not be considered important from a consumer acceptance standpoint, and that others experienced in the field may not consider this degree of change as loss of "high quality." We wish to state emphatically that the definitions are used only for illustration; entirely different definitions of that elusive but important concept, "the end of the high-quality life of this product" can quite justifiably be offered. Nevertheless, we have found this criterion of quality loss reproducible over a wide range of temperatures and over long periods of time *(7)*. Therefore, we have arbitrarily assumed that original "high-quality" was lost when 70% of our trained laboratory judges correctly selected the duplicate samples in a triangle test. The time required to reach the end of "high-quality" life, defined in this way, has been determined for several products at temperatures from 0° to 30° F.

The integration procedure gives, at any point of a time-temperature history, the accomulated amount of change in the product. As we have seen this can be expressed as the equivalent of exposure to a chosen reference temperature for a certain number of days. Now, if we have found that exposure of the *initial* product to that reference temperature for a certain number of days brings it to the end of its "high-quality" life as defined above, simple subtraction of the computed change, expressed in number of days at the reference temperature, gives the length of remaining "high-quality" life.[c] This concept of days of remaining "high-quality" life is illustrated in

[c] We are indebted to Howard Milleville and Karl Robe, both of *Food Processing*, for making the suggestion that led to this way of presenting the results.

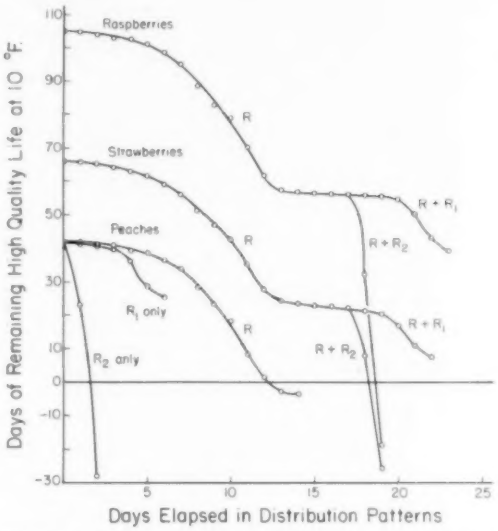

Figure 9. Effect of time in various distribution patterns on remaining "high quality" life.

Figure 9 for raspberries, strawberries, and peaches. Days of remaining "high-quality" life were determined after each day of experience in the distribution patterns, thus showing the average rate of loss of "high-quality" life as affected by temperature changes during distribution. It is readily apparent that distribution segment R_2 causes a very rapid loss in quality compared to R_1. Since the days of original "high-quality" life for peaches are much lower than those of strawberries or raspberries, they were all used up during distribution segment R. Therefore, segments R_1 and R_2 are plotted separately.

In frozen green beans, one of the best measurements for estimation of quality changes is the conversion of chlorophyll to pheophytin *(1)*. Consequently, this test has been used to determine the days of remaining "high-quality" life after exposure to the assumed distribution patterns shown in Figure 3. In this case the end of "high-quality" life was considered as the time required for the per cent chlorophyll retention to fall below 75. Since the mechanics of the calculations are similar to those already described for fruits, they will not be repeated. Figure 10 shows the effect of temperature in the distribution patterns on the rate of quality loss during exposure to those patterns. The graph indicates that the "high-quality" life of this particular lot of green beans at 10° F. is about 73 days and that this life is all used up after about 9 days in the 30° F. pattern, about 31 days in the 20° F. pattern, and that there is still about 53 days of "high-quality" life left in the product after completing 33 days in the 10° F. pattern.

Obviously, the primary aim is to deliver these frozen products to the consumer with as many days of remaining "high quality" life as possible. In order to do this, we have seen that temperature and distribution time must be kept as low as possible; otherwise all the "high quality" life will be used up before the product reaches the consumer.

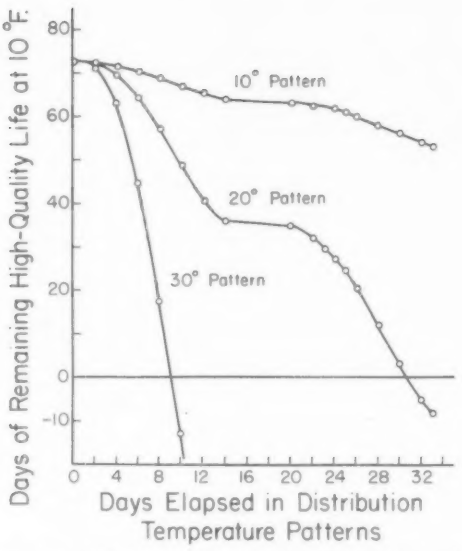

Figure 10. Effect of time in various distribution patterns on remaining "high quality" life in green beans.

SUMMARY

A procedure for the estimation of the accumulated change in a product which has experienced an irregular but known temperature history is described. The procedure involves determination of the area beneath the corresponding irregular time-temperature curve plotted on a transformed coordinate system derived from, and depending on, the observed relation between relative rate of change and temperature. The area beneath the curve is proportional to the total amount of change in the measured quantity. This is equivalent to an integration (by graphical means) over the temperature history. Using this procedure, good agreement was obtained between calculated and actual experimental values of color and ascorbic acid changes at various points in an irregular time-temperature pattern. This is in agreement with results from regularly fluctuating temperatures *(3)* and shows that temperature variation has no special effect. It is shown, therefore, that the quality loss or remaining "high quality life" of a product can be estimated from its temperature experience even though it is irregular, provided it is known.

Acknowledgment

The authors wish to express their appreciation to the following WURDD personnel: R. L. Olson and associates for the original rate data on green beans and to N. Floy Braeclin for the drawings.

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Poultry Tenderness. I.

Influence of Processing on Tenderness of Turkeys

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(Manuscript received June 10, 1958)

PRIOR TO 1954 many processors assumed, based on years of successful poultry processing, that no special procedures were needed to bring about optimum tenderness in commercially processed poultry. It has since become apparent that changes in processing and utilization methods, designed to increase efficiency, may interfere with the normal tenderization of poultry meat in the post mortem period. Studies to evaluate the influence of various processing factors on the ultimate tenderness of several types of commercial poultry products have been conducted by this Laboratory for several years. Because of the urgent need for information by industry, summaries of progress on this work have been published in several trade journals *(2, 4, 8, 13)* and presented at national meetings *(3, 6)*. The present report describes how the tenderness of turkeys is influenced by conditions of aging, scalding, and picking.

Practically all of the earlier research on poultry tenderness was carried out with chickens; these studies are briefly reviewed in our companion paper *(9)*. In essence, earlier work, principally by Lowe, Stewart and co-workers at Iowa State College, established the necessity for an aging period (8 to 24 hours) before cooking, but did not emphasize the possibilities of inadequate tenderization in frozen poultry because processing and marketing practices at that time provided more than adequate aging times. It was not until the poultry industry had made drastic changes in its methods of processing and utilization that it became apparent that poultry might not be subjected to adequate aging time between slaughter and cooking. Such changes included shifts from New York dressed to eviscerated poultry, warm evisceration, short chilling periods or none at all, rapid freezing, and cooking from the frozen state or with a minimum thaw. Since, as established by Koonz, Darrow, and Essary *(7)* with chickens, no appreciable tenderization can take place at commercial frozen storage temperatures, frozen poultry could be and in some cases was processed too rapidly to permit optimum tenderization.

In an evaluation by Klose and Pool *(5)* of the effect of increasing scalding temperature from 122° F. to 140° F. on the quality of 6-months-old Broad Breasted Bronze turkeys, no apparent toughening of the cooked breast muscle was oyserved although the cooked skin of the birds scalded at higher temperatures was definitely tougher. The absence of an effect with birds of this age is of interest in view of results to be described in which it is shown that an increase in toughness due to increased scalding treatment of immature turkey fryers is easily demonstrated but is not readily demonstrable with older and larger turkeys. Stadelman and McLaren *(11)* in a study of the effect of scalding conditions on the toughness of immature turkey fryers reported greater toughness with a 127° F., 55-second scald than with a 165° F., 9-second scald. It is now apparent, however, that the greatest differences observed, those between hand picked (dry) controls and scalded machine-picked turkeys, were probably more a reflection of the toughening effect of machine picking than of the toughening effect of scalding.

Several recommendations for proper aging of turkeys have appeared in the past several years *(1, 10, 12)* with emphasis on a 24-hour chilling period. Stadelman and Spencer *(12)* suggested, as an alternative to ice slush chilling, that turkeys could be packaged warm and air chilled, although they pointed out that the air-cooled birds developed a spotted appearance during cooling and a final frozen appearance not quite as good as ice-water-cooled birds.

GENERAL PROCEDURES

Turkeys were obtained from commercial flocks and were usually slaughtered at ages near typical, commercial marketing ages. In any particular experiment or comparison turkeys were of uniform origin, age, sex and weight. Unless specified otherwise in the description of each experiment, turkeys were fasted overnight with access to water, shocked with an electric knife for about 5 seconds, bled for 2 minutes by cutting the neck veins and arteries from the outside, scalded and picked as described below, eviscerated immediately, chilled or aged as described for each group, drained for about 10 minutes, packaged in evacuated, twist-sealed, heat-shrunk (190° F., 7 seconds) plastic film bags, frozen on open shelves in an air-blast freezer operating at −30° F. and 1300 feet per minute, and stored at 0° F. usually for a few days and not more than 3 weeks before cooking and evaluation.

For organoleptic evaluation of toughness or determination of the force necessary to shear the cooked meat, turkeys were either deep-fat-fried as halves or roasted as halves or whole birds. Deep-fat frying was accomplished by immersing the half turkeys in peanut oil at an initial temperature of 240° F. and then cooking at an oil temperature of 230° F. for periods varying with the bird weight but usually 50 to 60 minutes. For roasting, turkeys were held in a 300° F. rotating electric oven until the internal temperature in the breast reached 180° F., which required times varying with bird weight but usually around 4 hours. Cooked carcasses were allowed to cool for about 30 minutes for halves, 1 hour for whole birds, after which the various muscles used in the shear force determinations were separate, wrapped in wax paper to prevent moisture loss during the short delay (not more than 1 hour) before shearing.

Although several muscles from the breast and thigh were sheared and judged subjectively in initial experiments, the large outer breast muscle (*Pectoralis superficialis* or *Pectoralis*

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major) was finally selected as the most satisfactory standard sample because of its size, ease of separation and maximum sensitivity to processing factors with respect to changes in tenderness. A 1 x 1 inch cross section strip of the *Pectoralis superficialis* was cut out parallel to the grain of the muscle and 1 inch from the anterior edge. Six successive shears, across the grain of the muscle strip and spaced at ½-inch intervals along its length, were made with a Warner-Bratzler type shearing apparatus. This provided 12 shear-force values for each birds, or 72 values from which to calculate a mean for an experimental group of 6 turkeys.

A small percentage of all muscle strips tested developed shearing forces in excess of 50 lbs., resulting in rather violent recoils when the muscle finally yielded. To protect the mechanism of the shearing machine when the indicator passed the 50-lb. mark on the dynamometer scale, the machine was stopped and values for such shears were averaged in at a value of 50 lbs.

For organoleptic evaluation of tenderness corresponding pieces of cooked meat from the various experimental groups were submitted to each of seven members of a trained taste panel. No more than 3 samples were compared at any one time, and the samples were ranked for relative tenderness (1 for most tender).

EXPERIMENTAL WORK AND DISCUSSION

Initial experiments on aging conducted at the extremes of a normal aging period showed that relative shear-force values are a good reflection of relative tenderness assessed by a trained taste panel (Table 1). It is apparent in these experiments, and it will become increasingly clear in those to follow (Figure 1), that there is a wide range of shear-force values within each experimental group. The variability of shear force values within experimental groups was contributed mainly by bird-to-bird variation. Thus analysis of variance for typical groups indicated that bird-to-bird variance was in general much greater than three times the variance due to shear determinations within halves. In some experiments appreciable contributions also came from half-to-half variation, but in no case did an appreciable contribution to the variability within groups come from variation between shear values within halves (muscles). This is an indication of the relatively good reproducibility of the shear values obtained with the Warner-Brazler machine, and the greater importance of other sources of variation in establishing the standard error of the method.

The validity of any statistical analysis of experimental treatments with bird-to-bird variation as the error term may be questioned, because the variation does not behave as if it were distributed in a normal manner about the mean but often

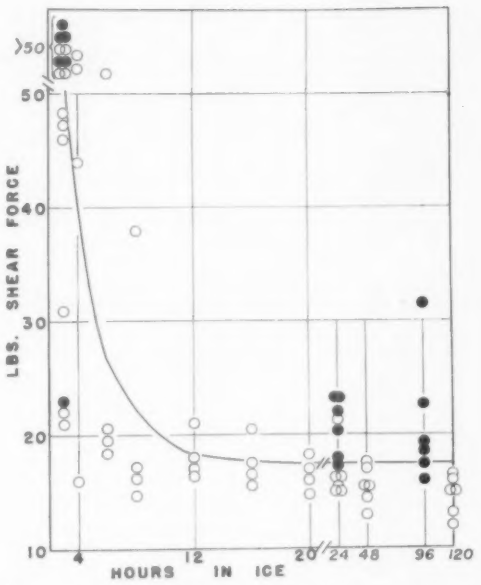

Figure 1. Average shear force values for the Pectoralis superficialis of individual 15-week-old, small white turkeys, which were scalded at 140° F. for 30 seconds, picked on a single drum, eviscerated, chilled, frozen, and deep-fat-fried as halves from the frozen state. Chilling was in ice slush for the first 8 hours, and in drained ice thereafter. Open circles refer to minimum exposure to the picking drum while closed circles are for birds receiving an additional 30 seconds of picking time.

appears to represent predominantly values either in the very tough region or in the tender region. Also the group error variances often increase markedly with increases in the group mean. Strict applicability of the F- and t-tests for estimating levels of significance is brought into question by these deviations from normal distribution and from common variance. Transformations in the raw data that have been recommended to eliminate these defects have only a partially corrective effect. Fortunately, most, if not all, of the experimental treatments to which we attribute practical importance result in differences between means of 50 to 100%, which for 6 to 8

TABLE 1

Effect of period above freezing on tenderness of turkey fryers[1]

Exp.	Period above freezing		Cooking method[2]	Shear force for breast muscle		Average taste panel rank for tenderness[3]
	Processing exclusive of chilling	Ice chilling		Average	Range	
	hrs.	*hrs.*		*lbs.*	*lbs.*	
A	0.25	0	Deep-fat	53	50–57	2.8
	1.6	0	fried	48	46–53	2.2
	2.2	20	halves	15	11–18	1.0
	0.25	0	Roasted	24	16–33	2.8
	1.6	0	whole	19	10–27	1.9
	2.2	20	birds	8	6–11	1.3
B	1.6	0	Roasted	11	10–14	2.5
	1.8	20	whole	7	3–11	2.0
	1.6	(0)[2]	birds	7	5–10	1.5
C	0.7	6	Deep-fat	54	45–60	2.0
	0.8	22	fried halves	13	12–14	1.0

[1] Three- 12-14-week-old Lancaster tom turkeys per group, scalded at 140° F. for 30 seconds, and picked on a single drum.

[2] All birds cooked from the frozen state except the 9th entry, which was thawed 2 hours in tap water and then held 20 hours in +35° F. air before roasting.

[3] Combined data for dark and light meat. 1 = most tender, 3 = least tender.

replications, are significant beyond any question raised by the abnormalities in distribution. As a rough estimate of the degree of significance to be attached to differences in average shear force values within an experiment, we have included with the tabulated data values of the least significant difference at a 1% level of probability, calculated by Fisher's t-test. Because of the deviations from normality, the use of a pooled error term in calculating t was avoided, and a separate error term was calculated from the data of each pair of treatments to be tested. It should be emphasized that while some of the small differences reported appear from application of the t-test to be statistically significant, they are not of practical importance in terms of consumer acceptability. For an overall perspective of treatment effects, three statistics are presented: the mean and range to express the general level and variability of tenderness; and, of great practical importance, the fraction of values falling within a tender range, which expresses the degree of completeness of practical tenderization so important to the elimination of consumer complaints.

Table 1 (experiment A) demonstrates that deep-fat frying produces a much tougher bird than roasting. It should be noted that cooking time for the fried half is about one-fifth of that for the roasted whole bird, which suggests, but certainly does not establish, the occurrence of some tenderization during the early part of the roasting period.

Time and temperature of aging. Results represented in Figure 1 and Tables 1 and 2 show the course of tenderization during aging at chilling (ice slush) temperatures. Tenderization is rapid and highly variable during the first several hours, and the ultimate tenderness to be achieved through aging generally develops within 12 hours. Data obtained in Experiment B (Table 1) and also from groups 8, 9, and 10 of Table 2 suggest that holding at chill temperatures after thawing is essentially as effective in tenderization as holding in a chilled state before freezing.

In Table 2 and some of the subsequent tables, it has been considered informative to express the shear force data for an experimental group in terms of the fraction of birds or halves that have an average shear force equal to or less than 20 lbs. Samples having shear values within this lower range were generally considered by the taste panel members to be adequately tender. Thus this fraction is a rough but meaningful measure of the completeness of tenderization within a group, or conversely is an indication of the residual number of tough birds in a group, which is the critical point from the processor's and distributor's standpoint.

TABLE 2

Effect of time and temperature of holding on tenderization of fryer-roaster turkeys[1]

Group	Holding condition			Shear force of *Pectoralis superficialis*	
	Ice chill	0° F. storage	37° F. air[2] after thawing	Average of 8 fried halves	Fraction with shear force ≦ 20 lbs.
	hrs.	*months*	*hrs.*	*lbs.*	
1	4	0.5	0	40+[3]	2/8[4]
2	8	0.5	0	21	6/8
3	20	0.5	0	17	8/8
4	4	3	0	40+[3]	0/8
5	4	6	0	33	2/8
6	4	9	0	30	0/8
7	20	6	0	14	7/8
8	4	0.5	4	26	3/8
9	4	0.5	8	19	7/8
10	4	0.5	12	19	7/8

[1] 4–6 fifteen week Beltsville turkeys per group, scalded at 140° F. for 30 seconds, picked on single drum; deep fat fried as halves from frozen state (groups 1 to 7) or from thawed state (groups 8 to 10). Least significant difference (1%) = 17.

[2] Applies only to groups 8, 9, and 10, which were thawed for 2 hours in tap water and then held at 37° F. for periods indicated.

[3] In this group, 5 out of 8 shear values were in excess of the machine limit of 50 lbs. and were averaged in at arbitrary values of 50 lbs. each.

[4] Should be read as two halves out of eight at or below 20 lbs.

Data in Table 2 show that holding turkeys for prolonged periods at a typical commercial frozen storage temperature (0° F.) neither increases tenderness to an optimum level (groups 4, 5 and 6) nor decreases tenderness (groups 3 and 7). These observations on absence of changes at 0° F. confirm the conclusions of Koonz, Darrow, and Essary *(7)* obtained with chickens held frozen for short (24 hours) periods of time.

The possibility of tenderization at a temperature just below or at the lower end of the freezing zone was investigated in two experiments in the 25° F. to 27° F. range. Results in Table 3 indicate that appreciable tenderization takes place in 1 to 2 weeks at 25 to 27° F., temperatures at which the carcass is still frozen hard. These observations suggest that if other quality factors could be controlled, tenderization could be accomplished after freezing and before normal thawing by adjusting the frozen storage temperature upward for a short, controlled period.

TABLE 3

Effect of holding at 25–27° F. on tenderization of fryer-roaster turkeys[1]

Holding condition		Shear force of *Pectoralis superficialis*
Ice chill	25–27° F. storage	(Average of 6 roasted birds)
hrs.	*days*	*lbs.*
2	0	20
2	7 (25° F.)	12
46	0	7
0	14 (27° F.)	12
24	0	7

[1] Beltsville Small White turkeys, 15 weeks of age, scalded at 140° F. for 30 seconds, picked on single drum, roasted whole from frozen state. Least significant difference (1%) = 5.

Young Bronze turkey hens of roaster size and age were found to be more tender after short aging times than fryer turkeys (Table 4). Even though roasted from the frozen state, which would minimize the tenderization ordinarily derived from thawing a large bird prior to roasting, the 4-hour-chilled turkeys had an average shear below the criterion of 20 lbs. The method and duration of cooking are probably influential factors in establishing these differences. Consistent but small decreases in shear occurred as the chilling period was increased to 8, 12, and 24 hours. However, the level of tenderness reached at early times indicates the less serious nature of the problem with older birds.

There have been frequent suggestions that tenderization might be accelerated by elevating the post mortem holding temperature, such as is done with beef. Tests conducted with eviscerated and bagged turkey fryers held for 4 hours in water at temperatures of 40°, 70°, and 100° F., respectively, and then frozen, provide no evidence for a commercially useful acceleration of tenderization at the higher temperatures (Table 5).

TABLE 4

Effect of chilling period on shear force of young bronze turkey hens[1]

Ice chilling period[2]	Shear force of *pectoralis superficialis* (lbs.)	
	Average of 12 halves	Range
hrs.		
4	18	12–33
8	14	12–18
12	12	8–14
24	11	7–15

[1] Six 20-week-old Broad Breasted Bronze turkey hens (15 lbs. average live weight) per group, scalded at 140° F. for 30 seconds, picked on double drum slant picker, and roasted whole from the frozen state. Least significant difference (1%) = 6.

[2] Birds were chilled in ice slush, which was allowed to drain freely after first 8 hours.

TABLE 5

Effect of temperature of holding before freezing on shear force of turkey fryers[1]

Bath temperature during 4 hours holding period	Shear force of *pectoralis superficialis*		Fraction with shear force of 20 lbs. or less
	Average of 10 halves	Range	
° F.	*lbs.*	*lbs.*	
40	37[2]	10–50+	2/10
70	44[3]	20–50+	1/10
100	30	24–41	0/10

[1] Five 17-week-old Beltsville White turkey hens per group, scalded at 140° F. for 25 seconds, hand picked, packaged in plastic bags and held in water bath at temperatures indicated, and deep fat fried as halves from frozen state.

[2] Three out of 5 birds had shear values in excess of the machine limit of 50 lbs., and were averaged in at arbitrary values of 50 lbs. each.

[3] Same as [2] except that 4 out of 5 birds were involved.

Scalding conditions. Experiments with 13-week-old Broad Breasted Bronze turkey fryers indicated that an increase in scalding temperature from 126° F. to 140° F., with scalding time constant, produced only 10 to 20% increases in shear force for the breast muscles. Evaluation was made of the effect of scalding time on the shear force of turkey fryers held in ice for 3, 24, and 70 hours, respectively, after slaughter and evisceration (Table 6). Doubling the period of scalding at 140° F. resulted in small (30–40%) increases in shear value for adequately aged birds, but no significant effect for the inadequately aged (3 hours' chilling) birds. The extreme variability encountered at early periods of aging could easily mask small differences due to scalding time.

Pickling conditions. In attempts to determine the causes of extreme variations in tenderness between birds within experimental groups, all possible sources of this variability in the normal sequence of processing steps were investigated. When the effect of machine picking of feathers was evaluated by a comparison with hand picked controls, a marked toughtening effect due to machine picking was observed. Table 7 presents data from 3 separate experiments on turkey fryers, all adequately aged for 24 hours at chill temperatures, in which the average shear forces for machine picked birds are at least 100% greater than those for hand picked controls. Although this effect is quite large for turkey fryers and chicken fryers *(9)*, similar comparisons with large turkey roasters, using several types of picking machines, have revealed no important differences between machine-picked birds and hand-picked birds. It will be recalled that an aging period is also not as critical for the larger turkeys as for the small, immature turkey fryers.

Additional studies on the toughening effects of various component machines used in a typical commercial line of rubber-fingered picking machines are summarized in Figure 2. The picking line was evaluated as 2 parts and the whole for the fried birds, and as 3 parts and the whole for the roasted

TABLE 6

Effect of scalding time on shear force of turkey fryers[1]

Scalding time at 140° F.	Chilling period in ice slush[2]	Shear force of *pectoralis super.*	
		Average	Range
seconds	*hours*	*lbs.*	*lbs.*
25	3	40+[3]	24–50+
25	24	13	11–18
25	70	13	10–17
50	3	38+[4]	21–50+
50	24	18	13–41
50	70	17	12–26

[1] Six 16-week-old Beltsville White turkey hens per group, scalded at 140° F., picked on double drum slant picker, and deep fat fried as halves from frozen state. Least significant difference (1%) = 4.

[2] Birds held in drained ice beyond 24 hours.

[3] Five of 12 halves had shear values in excess of machine limit of 50 lbs. and were averaged in at arbitrary values of 50 lbs. each.

[4] Same as in footnote [3] except that four halves were involved.

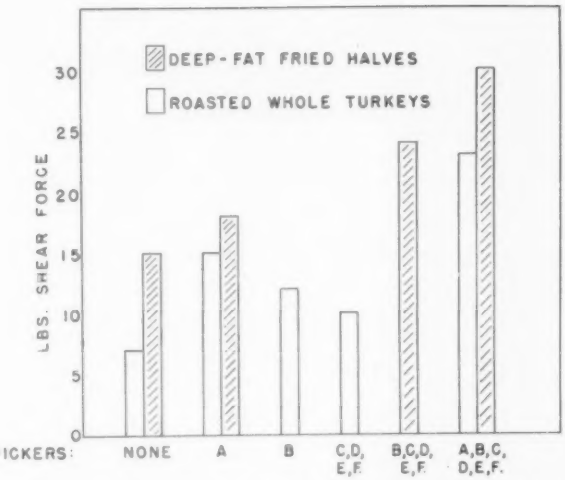

Figure 2. Toughening effect on Pectoralis superficialis of various portions of a commercial picking line. Hand picking was substituted for any phase of machine picking that was eliminated. Six to eight 15-week-old, small white hen turkeys per group, scalded at 139° F. for 40 seconds, picked, eviscerated, chilled for 24 hours, frozen and cooked from frozen state. Double drum pickers used were: A, 8-ft. rougher; B, 8-ft. reverse picker; C, 3-ft. neck finisher; and acting with neck suspension; D, 3-ft. hock picker; E, 8-ft. finisher; and F, 7-ft. washer.

TABLE 7

Toughening effect of machine picking versus hand picking for turkey fryers[1]

Picking procedure	Shear force of *pectoralis super.*		Fraction with shear force ≦ 20 lbs.
	Av. of 12 fried halves	Range	
	lbs.	*lbs.*	
Hand	23	16–50+[3]	9/12
Machine[2]	44	16–50+[4]	2/12
	Av. of 16 fried halves[6]		
Hand	12	8–16	16/16
Machine[2]	38	29–50+[5]	0/16
	Av. of 12 roasted halves[7]		
Hand	11	7–18	12/12
Machine[2]	22	9–34	6/12

[1] Six to 8 Beltsville White 14-15-week-old hen turkeys per group scalded at 138–139° F. for about 45 seconds; after picking and warm evisceration, chilled for 24 hours (7 hrs. in ice slush and 17 hrs. in drained ice); frozen and either fried or roasted from the frozen state.

[2] Commercial line of double drum pickers, consisting of 8 ft. rougher, 8 ft. reverse picker and 3 ft. neck finisher all acting on birds suspended by feet; and a 3 ft. hock picker, 8 ft. finisher and 7 ft. washer all cating on birds suspended by neck.

[3] One of 12 shear values in excess of 50 lbs., and averaged in as 50 lbs.

[4] Nine of 12 shear values in excess of 50 lbs., and averaged in as 50 lbs. each.

[5] Two of 16 shear values in excess of 50 lbs., and averaged in as 50 lbs. each.

[6] Least significant difference (1%) = 4.

[7] Least significant difference (1%) = 7.

birds. Toughening appears to be accumulative in that each additional picking machine or exposure to beating augments the degree of toughness already established. It should be emphasized that differences between hand picked and machine picked birds observed after 3–5 hours chilling could not be eliminated by extended and otherwise adequate chilling periods of 24 hours. Prediction of the toughening effect of any particular machine *a priori* would appear to be extremely diffi-

cult if not impossible at the present time, because in addition to duration of exposure that can be measured easily there is the factor of severity of exposure which could depend in complex ways on the type of machine and its adjustment and on the size of the birds.

Miscellaneous factors studied. In limited tests, factors that showed little or no toughening effect have included singeing, extent of struggling that turkey experiences before entering scald tank, and additional (3–6 minutes) delays between slaughter and scalding.

SUMMARY AND CONCLUSIONS

The tenderness of turkey fryers and some turkey roasters was studied as a function of conditions of scalding, feather picking, and holding (aging) at various temperatures before, during, and after frozen storage. Shear force values were found to be relatively good indices of toughness as subjectively expressed by the ranking of a trained taste panel. Tenderness of turkey fryers increased progressively with increase in aging (chilling) time up to at least 12 hours. Changes were rapid and highly variable within the first four hours. Very little if any additional tenderization took place from 12 hours to 24 hours post mortem, and even to a total aging time of 4 or 5 days. Turkey roasters appeared to be adequately tenderized after only 4 hours of chilling. For the same size and age of turkey, deep fat frying resulted in much toughter meat than roasting. Holding inadequately aged, frozen turkey fryers for as long as 9 months at 0° F. had no tenderizing effect, but holding at 25–27° F. for 1 to 2 weeks produced appreciable tenderization. Holding fryers in a thawed (35° F.) state after frozen storage had essentially as much tenderizing effect as an equal period of chilling before freezing. An elevation of the holding temperature to as much as 100° F. for 4 hours did not produce adequate tenderization.

Either increased scalding temperature or increased scalding time, within commercial ranges, had significant but small toughening effects.

Machine picking as employed in these studies resulted in cooked meat about twice as tough as for hand picked controls. The toughening effects of individual picking machines on a commercial line of machines were accumulative. Differences in shear values between machine-picked and hand-picked birds were essentially unaltered by extended chilling periods.

At present, optimum tenderness can be assured only through careful attention to chilling (aging) periods, feather picking conditions, and scalding practices.

Acknowledgments

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Poultry Tenderness. II.

Influence of Processing on Tenderness of Chickens

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OPTIMUM TENDERNESS, together with optimum flavor, is fundamentally important in the acceptance of meat-type chickens. Although tenderness was once considered a problem only with old hens and roosters, research at this laboratory and others has now established that young chicken fryers or broilers may reach the consumer's table with less than optimum tenderness if the effects of modern processing and utilization practices are not taken into account and suitable adjustments made. Studies reported were concerned with the normal post-mortem development of tenderness in chicken fryers, and particularly the effects on this development of processing factors such as scalding, feather picking, chilling, freezing, frozen storage, and holding after thawing. Similar supporting studies on turkey fryers are reported in a companion paper *(11)*.

Early pioneering research on tenderness in chickens by Lowe, Stewart, and co-workers at Iowa State College has been reviewed by Lowe *(14)*. As early as 1939 Lowe demonstrated that chickens (roasters) frozen within 2 hours after killing were less tender than those aged 24 hours before freezing. Stewart *et al. (19)*, in a study of tenderization of New York-dressed chickens (fryers) at 35° F., found that tenderness developed rapidly after the passing of rigor. Maximum tenderization occurred within 24 hours, with most of the tenderization taking place within the first 8 hours. Hanson *et al. (6)* reported that tenderness in New York-dressed chicken broilers increased rapidly during the first 3 hours of holding at 35° F. Holding beyond this time resulted in continued, gradual, relatively small and diminishing increases in tenderness. Similar studies by Lowe and Stewart *(14)* on chicken roasters and hens indicated that tenderization proceeded more slowly as the age at slaughter increased. Equivalent degrees of tenderness in the *Pectoralis superficialis* muscle were obtained for broilers in 3 hours, for roasters in 12 hours, and for fowl in 48 hours of aging. Temperature of aging, in the range from 32° F. to average room temperature, was shown by Stewart *et al. (14)* to have little effect on the rate of post-mortem changes. In fowl cooked 6 hours after slaughter, there was no difference in shear force or palatability between those chilled in ice and those held for 6 hours at room temperature.

The effect of freezing on tenderness has been the subject of several studies. In experiments with frozen broilers, Stewart *et al. (18)* found no difference in tenderness between groups given pre-freezing chilling periods of 2 hours and 18 hours, respectively, but a 48-hour thawing period prior to cooking probably eliminated any difference that was originally present. Carlin *et al. (2)* studied the extent of tenderization in roasters and fowl as a function of hours of holding at refrigerated temperatures and the additional effect of freezing and thawing. For birds aged less than 6 hours, freezing resulted in increased tenderness although it was clearly recognized by Carlin that this may have been due wholly or in part to the thawing and additional aging at thawing temperatures (24 hours at 39° F.) rather than the freezing itself. Aging, freezing, and several other processing factors were evaluated by Koonz *et a. (12)* for their effect on the tenderness of the principal muscles in the chicken broiler carcass. Ultimate tenderization was reached within 16 to 24 hours at 40° F. Freezing and holding at −20° F. for 24 hours essentially arrested any tenderization that would otherwise have occurred during that period. The authors concluded that freezing during the early post-mortem period fixed the state of tenderness existing at the time and complete tenderization was delayed until the tissues were defrosted. This study also revealed that increases in time of immersion of slaughtered carcasses in water at 140° F., from 30 seconds to a maximum of 180 seconds, resulted in corresponding increases in toughness of *Pectoralis superficialis*. Koonz also reported that cutting into the muscle immediately after slaughter resulted in a greater toughness than in an uncut control, at all stages of the normal aging period. This confirms the earlier work of Lowe and Stewart *(14)*, who found that the toughening effect was greater the sooner after slaughter the muscle was cut, although an effect could still be observed when cutting was delayed as long as 60 minutes after slaughter.

The possibility that massage might tenderize the muscles of chicken roasters aged for short periods (30 and 60 minutes) before cooking was investigated by Gainer *et al. (5)*, who found no appreciable differences in shear force between control and massaged birds. The aging periods were probably too short to have permitted an observation of the opposite effect, i.e. toughening, due to massage, since the control after 60 minutes of aging and immediate cooking was presumably still near a maximum degree of toughness.

Stimulated by industrial concern over consumer complaints of toughness in birds processed by modern methods, research on tenderization of poultry has been continued and expanded in recent years. In 1954, Stadelman and McLaren *(17)* reported that tenderness was reduced by increased scalding tem-

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perature and perhaps more by increased scalding time. However, the greatest differences observed appear to be expressions of differences in picking procedure, i.e., dry (hand) picking for the unscalded controls and machine picking for the experimental scalded groups. More recent work with hand-picked stewing hens by Shannon, Marion, and Stadelman *(16)* demonstrated an increased toughness due either to increased scalding temperature or to increased scalding time in the ranges of 120° to 195° F. and 5 to 160 seconds. However, the differences in toughness that occurred within the limits of temperature and time that would be necessary or practical in commercial plants were quite small. Dawson *et al. (3)* reported progressively more tenderization in fryers cooked from the frozen state as the interval between slaughter and freezing was increased from 40 minutes to 3, 6, and 24 hours, respectively.

Based on the experimental work to be reported here in detail, periodic progress reports and pertinent recommendations to the poultry processing industry on optimum tenderizing methods have been released widely *(1, 7, 8, 9, 10, 13)* over the past several years.

GENERAL PROCEDURES

Chickens used in any one experiment were commercially raised broilers from a single uniform lot, usually about 10 weeks of age and of one sex. Unless specified otherwise in the description of each experiment, the chickens were slaughtered and further processed in the manner described in our companion paper on fryer turkeys *(11)*. There was about a 40-minute interval between slaughter and the beginning of the chilling period, and about 25 minutes between the end of the chilling period and introduction into the blast freezer.

For evaluation of tenderness, the frozen halves were deep-fat-fried in peanut oil, the starting temperature of the peanut oil being 280° F. and cooking temperature 260° F. Total cooking time, adjusted to give an equivalent degree of doneness in all cases, varied with the weight but usually was about 30 minutes. Shearing of the *Pectoralis superficialis* was done as described for turkeys *(11)*, except that 5 successive shears were made across the grain of the whole muscle. This provided 10 shear force values for each bird, or 80 from which to calculate a mean from an experimental group of 8 chickens.

In some cases, particularly where cut-up chickens were evaluated, a modified procedure for determining the shear force was used in order to prevent the shortening and resultant change in cross section which often occurs during cooking, especially if the muscle is not held in place by its natural attachments in the intact carcass. The breast portion of the cut-up carcass was thawed in tap water sufficiently to permit removal of the intact *Pectoralis superficialis* without damaging it. Then the muscle was clamped in a special mold, immersed in boiling water for 30 minutes, removed to running tap water until chilled, and held in a refrigerator until ready to be sheared. The special mold, designed to prevent extensive shortening during cooking, consisted of 2 plates of 0.091-inch-thick duralumin, 7½ inches wide by 14 inches long, held apart by tubular spacers fitting around the machine screws which were used to clamp the two plates together. Strips one inch in width and parallel to the fibers were cut from the cooked muscle, resulting a cross section of about 0.4 sq. in. for shear force measurement with a Warner-Bratzler machine. Three to 6 shear values were obtained from each strip. Shear values for the boiled muscle strips are in a much lower range and are not comparable with values for the fried whole muscles, principally because of the different cross sections and cooking methods involved.

Shear force data have been presented in terms of the mean, the range, and the fraction falling at or below an arbitrarily assigned value considered to represent a reasonable degree of tenderness. While values for least significant difference between means have been calculated for a 1% level of probability by Fisher's t-test, the limitations on the applicability of analysis of variance as described for turkeys in a companion paper *(11)* also apply here.

The fraction of samples falling within an arbitrarily specified range of tenderness is of special interest and commercial importance because it is a measure of the completeness of consumer satisfaction, or conversely of the absence of complaints. For example, the average shear force of a group may be reasonably low, and yet the group may contain a few very high values which would represent consumer complaints at the market place.

EXPERIMENTAL WORK AND DISCUSSION

Time and temperature of aging. Figure 1 represents data from 3 experiments which illustrate how the rate of tenderization of chicken fryers changes over a 24-hour aging (chilling) period. Most of the possible change in tenderness took place within 4 hours, and very little if any change occurred after 12 hours. This is a confirmation of the early reports of Hanson *et al. (6)* at Iowa State College. Differences between experiments B and C in Figure 1 (freezing whole versus freezing cut-up birds), which might well be due to processing differences such as the cutting operation and the freezing rate, are not practically important since at adequate aging periods both experimental groups are within the tender range.

In addition Figure 1 provides evidence for the absence of tenderization at 0° F., and for the essentially equivalent tenderizing effects of aging after thawing compared to aging be-

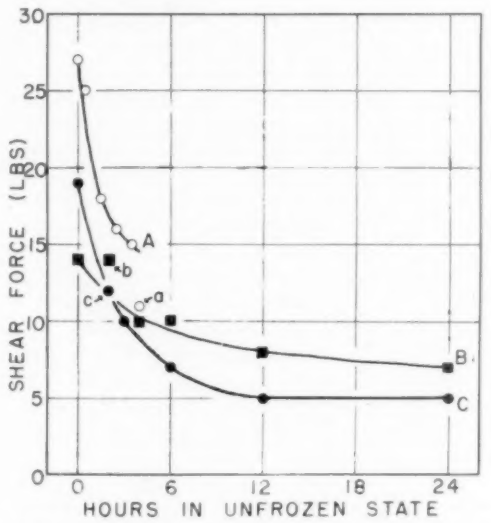

Figure 1. Course of tenderization of ready-to-cook meat-type chicken fryers as a function of aging time in ice slush. Points are averages for 4 to 6 10-week-old birds of shear forces for Pectoralis superficialis from halves or pieces deep-fat-fried from the frozen state. Times as shown do not include the one-hour required for processing exclusive of chilling.

A. Scalded at 140° F. for 30 seconds, hand picked, and frozen as whole, ready-to-cook carcasses. Individual point "a" represents value for group frozen without any ice chilling period but thawed and held for 4 hours at 35° F. before frying.

B. Scalded at 128° F. for 60 seconds, picked on a single drum, and frozen as whole ready-to-cook carcasses. Individual point "b" represents value for group held at 0° F. for 4 months before frying.

C. Same as B, except that birds were cut up after chilling and before freezing. Individual point "c" represents value for group held at 0° F. for 4 months before frying.

fore freezing. Points "b" and "c" represent shear forces of groups held at 0° F. for 4 months, after an initial 2-hour chilling period. Point "a" represents group frozen without a chilling period but held 4 hours at chill temperatures after thawing. These data confirm earlier work of Koonz *et al. (12)* and recent findings for fryer turkeys *(11)*.

There is some evidence for beef *(15)* and possibly for chicken *(12)* that meat cooked immediately after slaughter is somewhat more tender than meat cooked shortly thereafter but before going into rigor. To test this point, birds were cooked 15 minutes after slaughter, and after holding for successively longer periods in ice slush up to 3½ hours. From the limited number of time periods studied, there was no evidence for the existence of a lesser degree of toughness preceding maximum toughness.

Some processors have suggested that chilling in the dressed state permitted more effective tenderization than chilling in the ready-to-cook state. Comparisons of the tenderizing effect of chilling in the dressed, ready-to-cook, and ready-to-cook cut-up states (Table 1) revealed no practically important difference in shear force values between birds chilled in dressed versus ready-to-cook state, for any of the 3 chilling periods studied. There appeared to be a small toughening effect produced by cutting up before chilling.

Tanaka and Tanaka *(20)* have reported that weep and thawing drip of whale meat can be minimized by freezing in the early post-rigor or in the pre-rigor state and then removing contractibility by holding at 28.4° F. for 5 days or at 26.6° F. for 10 days before defrosting. This suggested that aging and tenderization might also occur in poultry meat in this intermediate range of temperatures between a completely frozen and a completely thawed condition. Experiments to test this hypothesis, summarized in Table 2, established that appreciable tenderization could be effected by holding the frozen (hard) carcasses for a period of days at 27° F. or even slightly lower. Factors that need to be evaluated before practical use of this tenderizing method could be considered would include the combined effect of storage time and temperature in the 25° to 28° F. range on tenderization, surface darkening, microbial growth, and rancidification.

Scalding conditions. Four experiments (Table 3) were run to determine the effect of variation of scalding temperature and scalding time on tenderization. The results are in general agreement with those of Shannon *et al. (16)*. Increase in scalding temperature from 126° to 140° F. resulted in a small increase in toughness. Doubling the scalding time at 140° F. also produced a small increase in shear force and moreover a marked decrease in the fraction within the tender range. It was not until the scalding time was extended to 3 times the ordinary maximum commercial time (experiment H and J) that marked increases in average toughness were noted. The effect of scalding conditions is evident in incompletely aged birds (2 to 3 hours' chilling) and persists in the adequately aged (24 hours) groups.

Picking procedures. The picking variable was first investigated because it was felt that the more or less random action of the rubber fingers of mechanical pickers on the carcass might contribute to the extreme variability in rate of tenderization encountered in the early post-mortem period. When hand picking was introduced as an experimental negative control, it was soon apparent (Table 4) that the action of a rubber-fingered mechanical picker resulted in a greater ultimate toughness after aging than did picking by hand. The drastic reduction in the fraction of the birds within the tender

TABLE 1

Comparative tenderization by chilling in dressed, whole ready-to-cook and ready-to-cook cut-up form

Chilling period in ice slush hrs.	Shear force (lbs.) of Pectoralis superficialis of deep-fat-fried halves[1]							
	Chilled in dressed state			Chilled in ready-to-cook state			Chilled in cut-up state	
	Aver.	Range	Fraction ≦ 8	Aver.	Range	Fraction ≦ 8		
1	19.6	7–37	1/8	19.6	7–39	2/8		
3	12.2	6–23	4/8	10.4	6–25	5/8		
23	4.7	4–6	8/8	6.4	5–8	8/8		
	(Shear values below on boiled, excised muscle)[2]							
	Aver.	Range		Aver.	Range		Aver.	Range
3	4.0	2–6		4.6	3–8		5.4	4–9
21	2.0	1–3		1.9	1–3		3.7	2–6

[1] Eight 14-week-old Indian River x Lancaster cockerels per group, scalded at 130° F. for 45 seconds, picked on single drum picker with moderate pressure, frozen as whole, ready-to-cook carcasses, and deep-fat-fried as halves from the frozen state. For 23 hrs. chill, Least Significant Difference (1%) = 1.5.

[2] Eight 10-week-old Indian River x Delaware cockerels per group, scalded at 128° F. for 60 seconds, picked on single drum picker for minimum time; after chilling in drained ice as indicated, the whole birds were reduced to an equivalent commercial-type cut-up condition and frozen in telescoping cartons with the two breast pieces packed on top just underneath the lid. For evaluation of tenderness, one breast piece was thawed enough to remove the *Pectoralis superficialis*, and this muscle was boiled for 30 minutes and sheared as described in General Procedures. Least Significant Difference (1%) = 1.8.

TABLE 2

Tenderization in the temperature range of 25° to 27° F.

Expt.	Holding conditions other than −20° F. storage		Shear force of *Pectoralis superficialis* (lbs.)				
			Fried halves			Boiled muscles	
	Ice slush	25°–27° F.	Aver.	Range	Fraction ≦ 8	Aver.	Range
	hrs.	*hrs.*					
D[1]	24	0	6	4–11	6/8	4	3–7
	1	0	11	6–18	2/8	10	5–23
	1	72 (25° F.)	9	6–13	4/8	7	6–10
	1	48 (27° F.)	7	5–9	5/8	5	4–7
E[2]	24	0	4	3–5	8/8	4	3–5
	1	0	18	6–31	5/17	12	5–24
	1	60 (25° F.)	8	6–9	3/6	7	5–9
	1	112 (25° F.)	7	5–9	8/9	6	4–8
	1	163 (25° F.)	6	4–9	7/8	4	3–4

[1] Eight 13-week-old Indian River x Delaware mixed sex chickens per group, scalded at 128° F. for 60 seconds, picked on single drum with minimum force, chilled in ice slush as indicated, frozen in air-blast at −25° F., and held as indicated and at −20° F. until cooked and sheared. Least Significant Difference (1%) = 4.

[2] Same conditions as described in footnote 1 except that birds were 11 weeks old, and group sizes were from 6 to 17 birds each as indicated. For fried halves, Least Significant Difference (1%) = 7. For boiled muscles, Least Significant Difference (1%) = 4.

TABLE 3

Effect of scalding conditions on shear force of chicken fryers

Expt.	Scalding time	Chilling time in ice slush	Shear force (lbs.) of *Pectoralis super.* of deep fat fried halves					
			126° F. scalding temperature			140° F. scalding temperature		
			Aver.	Range	Fraction ≦ 8	Aver.	Range	Fraction ≦ 8
	sec.	*hrs.*						
F[2]	60	2	15.4	8–22	1/16	17.6	11–22	0/16
G[2]	25	3	.....	.....	.....	11.6	6–19	5/16
	50	3	11.3	5–30	8/16	14.4	11–21	0/16
	25	22	.....	.....	.....	9.9	6–14	7/16
	50	22	8.0	5–19	11/16	12.2	8–19	1/16
H[2]	30	3.5	.....	.....	.....	14.6	6–21	4/12
	180	3.5	.....	.....	.....	20.6	18–24	0/12
J[4]	30	24	.....	.....	.....	10.3	8–14	2/12
	180	24	.....	.....	.....	25.2	18–32	0/12

[1] Eight 10-week-old White Rock cockerels per group, picked on a single drum with minimum force, warm-eviscerated, after chilling packaged and frozen in air blast at −30° F., 1300 f./m., and fried as halves from the frozen state. Least Significant Difference (1%) = 3.6.

[2] Same as in footnote 1, except that cockerels were Indian River x Delaware Cross. Least Significant Difference (1%) = 3.1.

[3] Six 11-week-old Indian River x Delaware cockerels per group, hand picked, but otherwise processed as described in footnote 1. Least Significant Difference (1%) = 5.4.

[4] Same as in footnote 3, except that birds were 15 weeks old. Last Significant Difference (1%) = 3.7.

TABLE 4

Comparison of shear forces of hand-picked and machine-picked chicken fryers

Expt.	Chill period:	Shear force (lbs.) of *Pectoralis superficialis* of deep-fat-fried halves								
		3 hrs.			24 hrs.			96 hrs.		
	Picking procedure	Aver.	Range	Fraction ≦ 8 lbs.	Aver.	Range	Fraction ≦ 8 lbs.	Aver.	Range	Fraction ≦ 8 lbs.
K[1]	Hand	10	6–25	7/16	6	5–10	15/16	....	.....	.....
	Single drum, minimum	11	6–30	8/16	8	5–19	11/16	....	.....	.....
	Single drum, excessive	16	7–24	2/16	17	11–25	0/16	....	.....	.....
L[1]	Hand	14	6–27	4/16	6	4–9	15/16	5	4–8	16/16
	Single drum, minimum + 30 sec.	11	7–19	4/16	8	5–15	10/16	9	7–20	9/16
	Double drum, 40 sec. total	13	9–34	0/16	9	5–11	7/16	10	6–15	3/16
M[2]	Hand	19	6–42	4/16	6	4–7	16/16	6	4–8	16/16
	Single drum, minimum + 30 sec.	13	6–30	3/16	8	5–15	9/16	12	7–20	1/16
	Double drum, 40 sec. total	10	7–15	6/16	9	6–16	9/16	9	6–12	7/16
				Fraction ≦ 10 lbs.			Fraction ≦ 10 lbs.			
N[3]	Hand	12	9–21	5/12	10	8–14	6/12	....	.....	.....
	Single drum, excessive	....	.....	.....	22	12–31	0/12	....	.....	.....

[1] Eight 10-week-old Indian River x Delaware cockerels per group, scalded at 126° F. for 50 seconds, warm-eviscerated, after chilling packaged and frozen in air blast at 30° F., 1300 f./m., and fried as halves from the frozen state. For Expt. K, Least Significant Difference (1%) = 5. For Expt. L, Least Significant Difference (1%) = 5 (3 hrs. chill); 2 (24 hrs. chill); 2 (96 hrs. chill).

[2] Same as in footnote 1, except that birds were 16 weeks old. Least Significant Difference (1%) = 10 (3 hrs. chill); 2 (24 hrs. chill); 3 (96 hrs. chill).

[3] Six 15-week-old Indian River x Delaware cockerels per group, scalded at 140° F. for 30 seconds, otherwise as described in footnote 1. Least Significant Difference (1%) = 5.

range is particularly significant. It was also found that the degree of toughening could be increased by increasing the duration or severity of the beating action of the mechanical pickers. The significance of the greater shear values for hand than for machine-picked in the inadequately (3 hours) aged birds of experiments L and M is not known, although they are probably reflections of the extreme variability found in tenderization rates during the first few hours post-mortem.

TABLE 5

Effect of interval between slaughter and excessive beating on ultimate shear force[1]

Time of application of 30 sec. beating in excess of minimum	Shear force (lbs.) of Pectoralis super. of cooked halves				
	Fried halves			Boiled muscles	
	Aver.	Range	Fraction ≦ 8	Aver.	Range
At once.....	9.6	5–14	3/8	6.8	4–10
After 1 hr. chill.....	6.4	4–9	7/8	5.1	3–9
After 3 hrs chill.....	6.4	4–9	7/8	5.2	3–8
After 24 hrs. chill.....	5.5	4–6	8/8	4.5	3–6

[1] Eight 13-week-old Indian River x Delaware mixed sex chickens per group, scalded at 128° F. for 60 seconds, picked on single drum with 30 seconds additional beating at times indicated above, chilled for a total period of 24 hours, frozen in air blast at −30° F., 1300 f./m., sawed in half, one half being deep-fat-fried from the frozen state, and the other half thawed and the excised muscle cooked in boiling water. Least Significant Difference (1%) = 3.5 (fried halves); 2.6 (boiled muscles).

In order to understand better the nature of this beating action, the ultimate toughness after 24 hours' chilling was measured as a function of the time elapsing between slaughter and application of an excessive beating. Results in Table 5 indicate that the muscle is most susceptible immediately after slaughter at the normal picking time and beatings after longer intervals are progressively less harmful. Relationships of this beating effect, as well as the scalding and aging effects, to the biochemical changes that occur in the muscle during the early post-mortem period are reported by de Fremery and Pool *(4)*.

SUMMARY AND CONCLUSIONS

Tenderness of chicken fryers was studied as related to conditions of scalding, feather picking, chilling or aging, and frozen storage. Effects reported for turkey fryers *(11)* were in general observed for chickens, too, although the effects with chickens were not as large and possibly not as critical commercially. Significant but small increases in toughness were

produced by increasing either the scalding temperature or the scalding time within the commercial ranges. The ultimate toughness after aging increased with extent of beating action incurred by the carcass during feather removal. Beating exerted its greatest toughening effect when applied immediately after slaughter. Beating delayed 1 to 3 hours after slaughter had less effect.

Determinations of toughness as a function of temperature and time of aging showed that most tenderization takes place within 4 hours at chill temperatures. Very little occurs after 12 hours. No appreciable tenderization occurred at 0° F. over a 4-month period, but significant tenderization took place in frozen carcasses held at 25° to 27° F. for several days. Tenderization arrested by freezing proceeded at about a normal rate on thawing. Cutting up the carcass in the early post-mortem period had a small toughening effect.

The results support recommendations for minimum scalding and beating treatments consistent with complete, economical feather removal, and for an adequate aging period, which potentially can be imposed either in the chilling, frozen storage, or thawing steps.

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Color Standards for White Potato Granules

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WHITE POTATO GRANULES are dehydrated precooked white potatoes in granular form. Color is generally an index of over-all quality of potato granules, with darker colors associated with a scorched or otherwise improperly processed product. It was the aim of the present work to prepare permanent color standards which would be useful in procurement and for quality control during production. For this application the lightness attribute of color is of predominant importance. The color of potato granules is not sufficiently stable to make feasible the use of selected granule samples themselves as standards. Instead, formulations were developed which were based on glass beads comparable in size to the individual potato granules. The beads when mixed with dry powdered inorganic pigments provide satisfactory appearance as well as color matches for the granules. Three such formulations were made, representing colorwise the borderline of acceptability for military procurement, and typically good (light) and typically poor (dark) granules *(1)*.

THE GRANULES SELECTED FOR COLOR MATCHING

From a variety of sources about 40 samples of potato granules were collected, ranging in color from very good to very poor. Samples were grouped into 3 categories on the basis of color and classified as products of good, borderline and poor color. One sample from each category was selected as representative of the group and used for the development of the permanent color standards. The range of color between the selected good and poor sample was small; the color designation according to the ISCC-NBS method *(3)* for all 3 samples being either yellowish white or pale yellow. Spectral reflectance data (relative to magnesium oxide) are shown for the potato granules as the dotted curves in Figure 1. Chromaticity coordinates based on the 1931 CIE standard observer and Illuminant C, computed by the method of weighted ordinates from the reflectance values and standard colorimetric data *(2)* are listed in Table 1. The color difference, $\Delta E = 3.8$ NBS units, between borderline (B) and good (G) granules was essentially equal to that between borderline and poor granules (P), $\Delta E = 3.9$ NBS units. In terms of lightness or luminous reflectance, ΔR_c, the difference between B and G was 6.1%, and between B and P was 5.5%. The chromaticity coordinates and luminous reflectances of the granules were adopted for specification purposes *(4)*, and preparation was undertaken of standards which would match these specifications within small tolerances.

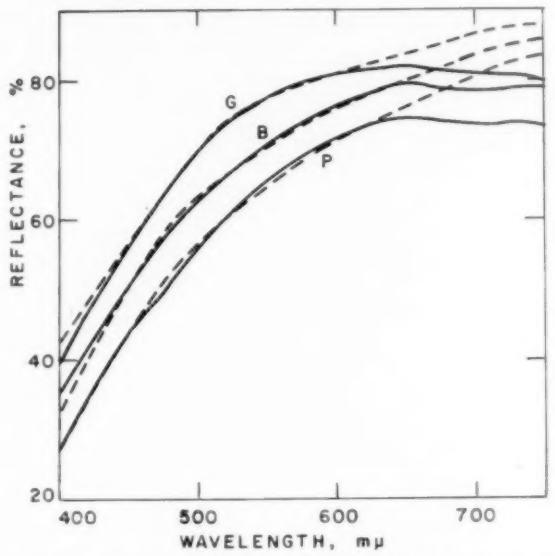

Figure 1. Reflectance spectra of good, borderline and poor potato granules (dotted lines), and matching permanent color standards (solid lines).

[a] Eastern Utilization Research and Development Division, Agricultural Research Service, U. S. Department of Agriculture.

TABLE 1

Colorimetric data on white potato granules and permanent color standards; CIE data are based on 1931 standard observer and Illuminant C

	Potato granules			Color standards		
	Good	Borderline	Poor	Good	Borderline	Poor
Chromaticity coordinates x	0.3372	0.3427	0.3496	0.3377	0.3432	0.3503
y	0.3500	0.3530	0.3580	0.3518	0.3531	0.3603
Luminance reflectance, R_c, %	76.9	70.8	65.3	76.8	70.8	65.4
Dominant wavelength, λ, mμ	574.6	576.0	576.8	574.2	576.1	576.3
Excitation purity, P, %	16.3	18.6	21.8	16.9	18.7	22.6
Munsell notation	5.5Y 8.9/1.9	3.5Y 8.6/2.3	2.5Y 8.3/2.8	5.5Y 8.9/2.0	3.5Y 8.6/2.3	3.0Y 8.3/2.9
Color difference, Δ E, between granules and standards, NBS units	.....	.....	.....	0.9	0.2	1.0
Lightness difference, Δ R_c, between granules and standards, %	.....	.....	.....	−0.1%	0.0%	+0.1%

To be lifelike, color standards must approximate the texture of the granules judged. Granules are simply individual cells of potato tissue, for the most part intact; the thin cellulosic cell wall encloses the original cell contents, obviously modified by gelatinization of the starch and disappearance of the starch granules during the cooking. Like the potato cells the potato granules are roughly isodiametric. Under the microscope they present an appearance resembling that of fragments of glass, somewhat irregular in shape, and with rounded and roughened surfaces. The distribution of sizes in a 200-gram sample of granules was determined by sieving, with the results shown in Table 2. The small amount of material retained on 40- and 60-mesh sieves consisted mostly of vascular fibers, peel fragments and clumps of granules. For the whole sample the maximum in the weight distribution versus size curve corresponded to a diameter of about 150 μ.

TABLE 2

Size distribution in a sample of potato granules

Sieve number		Weight per cent
Passed	Retained on	
40	60	0.8
60	80	16
80	100	19.5
100	120	49.5
120	140	0.5
140	170	5.5
170	270	7.5
270	325	0.8

MATERIALS FOR THE COLOR STANDARDS

The principal component of the standards was fine glass beads of the sort used in projection screens. In form the beads are essentially spherical and their light-diffusing characteristics are considerably different from those of potato granules of the same size; even when properly pigmented, mixtures based on 150 μ diameter beads were so grossly inadequate in texture as to be unacceptable as color standards. It was found, however, that spherical glass beads of nominal diameter 75 μ would make an acceptable base for the color standards, and as such comprised 80 to 90% of the weight. As a lightening agent a finely powdered white glass with reflection qualities approaching those of MgO was used, in proportions of 10 to 20%. Three colorants were used, in total amount of 0.4 to 0.6%. They were pigments employed in production of vitreous tiles and had the following characteristics:

Color designation (*3*)	Munsell notation	
Light yellow	2.5Y	8.5/6
Moderate yellow	5.0Y	8/7
Moderate orange yellow	7.5Y	7.5/6

The beads as received from the supplier were too heavily contaminated with dark material to be useful directly. Oversize beads and part of the dark contaminant were eliminated by sieve-classification, discarding all material retained on a 100-mesh screen. Happily the remaining dark contaminant was strongly paramagnetic and could be removed by passing a fine stream of the beads over an apex of the pole of a small horseshoe magnet. After being cleaned in this way the entire quantity of beads, amounting to about 18 lbs., was thoroughly mixed.

PREPARATION AND TESTING OF THE COLOR STANDARDS

Trial formulations were prepared in approximately 20-g. amounts. Chosen quantities of the colored pigments were tumbled with a somewhat larger weight of the white glass powder. This was done in a 1-ounce square glass jar containing several ¼ in. and ⅜ in. stainless steel balls, and revolved on the rollers of a miniature ball mill. This initial mixing occupied 1 to 3 hours. When microscopic examination showed that the colorant particles were well dispersed, the remainder of the glass powder was introduced and the tumbling was resumed. Finally, the glass beads were added and mixed with the powders in a similar manner; impact of the balls was not so severe as to damage the beads.

When mixing was complete the spectral reflectance of the sample was recorded over the range 400 to 750 mμ by means of a General Electric spectrophotometer[b] (Figure 1). The sample was contained in a metal cell, equipped with a thin glass window, and so designed that reproducible filling was achieved easily. The depth of the sample was about 1 cm. The comparison surface was MgO viewed through glass from the same piece used in the window of the sample cell. CIE data were derived from recorded reflectance curves with the aid of a General Electric semi-automatic tristimulus integrator and the method of 30 selected ordinates.

When a sufficiently close chromaticity and lightness match for the potato granules was achieved, larger batches were made in essentially the same manner. It was not possible to duplicate mixing conditions precisely, and minor adjustments in the proportions of colorants had to be made in all of the larger batches in order to obtain satisfactory color. In our experience the larger batches were slightly darker than was expected from the formula worked out in the small scale trials. Reflectance values for the final color standard mixtures were read from the spectrophotometer dial at 10 mμ intervals, and converted into CIE data by the weighted ordinate method. The closeness of the spectral match between the granules and color standards is evident from Figure 1.

PACKAGING AND MODE OF USE

As containers for the color standards and the potato granule samples to be graded, 2-ounce square, wide-mouth flint glass jars provided a workable compromise among optical quality, cost and other practical requirements (*1*). The jars are cheap enough that, with small total outlay, a sufficient number can be selected with suitably flat faces, adequate uniformity of wall thickness and freedom from bubbles and other imperfections. The wide-mouth glass jars are easily filled and emptied and easily cleaned. Compared with cells fabricated from colorless plastic they are resistant to scratching, solvents and frictional electrification. Compared with fused glass cells of even quite ordinary optical quality, they are far less expensive. Compared with both plastic and glass cells, they offer the advantage of reliable, convenient closure through screw caps. Although glass jars with rectangular rather than square cross-section would be more economical of the color standard mixtures, no such jars of adequate optical quality could be obtained. A worthwhile economy in the color mixture was achieved by inserting a capped glass vial at the center of the 2-ounce square jars before filling.

Decalcomanias identifying the color standards were applied to inside surfaces of selected jars, the jars were filled, the necks wadded with cotton, and black plastic screw caps secured by means of cellulose acetate cement.

A technically adequate, simply built, inexpensive illuminated chamber was devised for making color comparisons between granule samples and the standards (Figure 2). In essence this is a plywood box 22 in. long, 15 in. wide and 19 in. high, open at the front except for a strip 7 in. wide extending downward from the top. The strip has the dual function of preventing light from the lamps from striking the observer's eyes and minimizing the effect of room lighting on the illumination of the samples. The chamber is illuminated by two 15-watt fluorescent "daylight" lamps mounted with white enameled reflectors on the ceiling. The lamps are spaced equidistant from each other and from the front and back of the box. The daylight lamps provide light approximating Illuminant C in quality, and at a level of about 200 foot-candles in the area where the color comparisons are made. The interior of the cabinet, and the sample holder, are finished in dull black.

[b] Mention of specific firms and companies does not imply endorsement of their products by the Department of Agriculture to the possible detriment of others not mentioned.

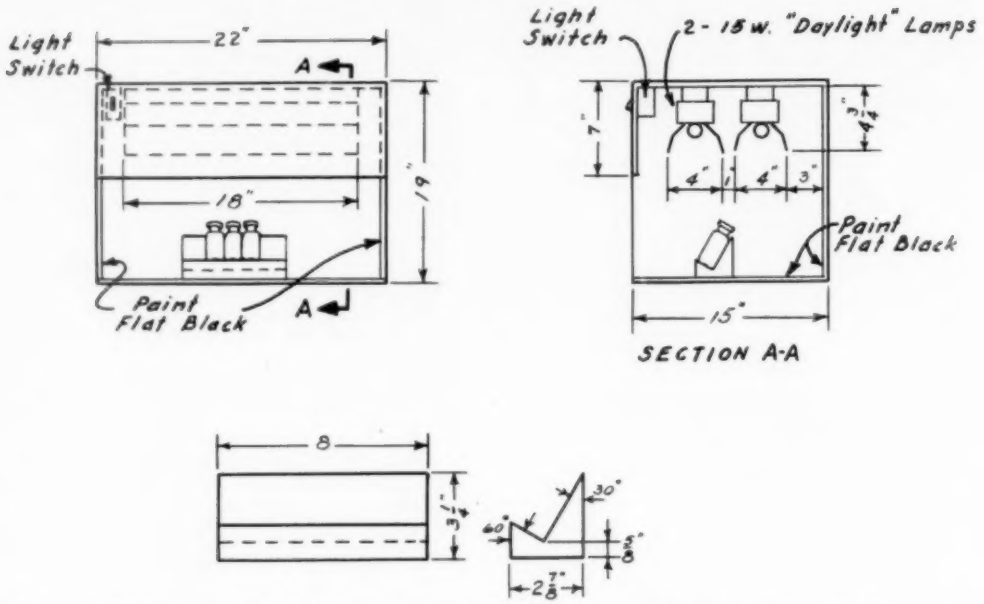

Figure 2. Cabinet and sample holder for color comparison of potato granule samples and standards.

Jars containing samples and standards are placed on a rack as illustrated in Figure 2. The axis of the jars is 30° from the vertical. A thin blackened metal sheet with rectangular apertures was put in front of the jars to mask out the edges, shoulders and caps. At the cost of cumbersomeness this produced an esthetic improvement but no advantage in color discrimination, and was discarded.

DISCUSSION

Twenty-five sets of the 3 color standards were prepared. Chromaticity and other data on the standards are listed in Table 1. The lightness difference between granules and standards is gratifyingly small, 0.1% or less. Color differences between granules and standards, computed by the Nickerson-Stultz formula (*2*, page 265), with f = 40, are also quite small.

It was noted that the granule samples on which color specifications were based became strikingly yellower during 2 years' storage at room temperature in the dark in glass containers, compared with the same samples kept at 40° F. Spectrophotometrically the refrigerated granules were essentially unchanged, and visually matched the permanent color standards very well.

SUMMARY

Color is generally an index of over-all quality of potato granules, with darker colors associated with scorched or otherwise improperly processed granules. A color specification based on the spectral reflectance of selected granule samples has been incorporated into the military specifications for white potato granules. Three stable color standards, representing the borderline of acceptability and typically good and typically poor granules, have been prepared. Twenty-five sets of these standards have been transferred to the Quartermaster Food and Container Institute for the Armed Forces for use by QM inspectors and for loan to commercial producers of granules. Inexpensive, technically adequate illuminators and containers have been devised for comparison of granule samples with the color standards.

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Clinical and Epidemiological Observations on the Influence of Fats in the Diet[a]

(Manuscript received July 19, 1958)

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ONE OF THE THINGS of importance in connection with the clinical and epidemiological observations on the influence of fats in the diet is that components of nutrition other than fat are involved in the picture of atherosclerosis. There is much emphasis on the question of fat. I would like to call attention to good evidence showing that other aspects of nutrition are also involved.

The first point to be made involves a clinical study which emphasizes, at least to us, the importance of serum cholesterol. This problem was well described in the first part of Dr. Stamler's paper.[b] There is still considerable doubt among physicians as to whether or not the elevation of serum cholesterol has anything to do with this problem. Personally, I think it has a lot to do with it. It is not the sole factor, but it is certainly an important factor. As Dr. Stamler pointed out, in order to produce atherosclerosis experimentally, one really has to find some mechanism to elevate the serum cholesterol.

TWO HUNDRED AND SEVENTY-THREE OUT OF TWO THOUSAND

Several years ago we obtained the serum total cholesterol level in sera from over 2000 men between the ages of 25 and 75. Two hundred and seventy-three of these men had had myocardial infarctions. The cholesterol values of the men who had a heart attack were compared with the 1920 men who had not. A definite difference was found between the cholesterol levels of these two groups for all ages. Up until the age of 55, there is a very marked difference. For example, approximately 70 people who had developed heart attacks at age 45 had an average cholesterol value of about 280 mg. per cent, whereas, for the 340 or 350 who had not, the average cholesterol value was 240 mg. per cent. These data do not mean that you can lean back and relax if you are 45 years of age and your cholesterol level is 240 mg. per cent or less. It only means that your cholesterol is about the average of a sizeable group of that age who at the time our study was terminated had not had a heart attack.

The limits of one standard deviation of the average cholesterol values were established from the same data of the 273 men who had a heart attack and of the 1920 who had not. For men age 45 who developed a heart attack, the lower limit cholesterol figure is approximately 212 mg. per cent. In other words, $\frac{5}{6}$ of these men had serum cholesterol levels above 212 mg. per cent. So, if you are a male, age 45, and have a cholesterol level below 212, then one can frankly say that you can dissociate from, and keep out of, $\frac{5}{6}$ of a group of 273 people who had developed a heart attack. That is a much better position to be in than to be in the group of apparently well men who had cholesterol levels above 212 mg. per cent and who had not developed a coronary, but anyone of whom might have had one a day or a week after our study was terminated!

These data show that people who have elevated serum cholesterol levels are much more likely to develop coronary artery disease than those who have low cholesterol levels; they do not say that a rise in serum cholesterol *causes* coronary heart attacks or coronary infarctions.

RURAL GUATEMALANS AND U. S. URBAN MALES

In cooperation with the Institute of Nutrition in Central America and Panama, we have done some epidemiological type of studies comparing about 200 male adult, rural Indians living in the highlands of Guatemala, outside of Guatemala City, with data obtained from a far larger number of U. S. urban males. Two dietary differences were of interest. First, there is a big difference in the per cent of calories coming from fat. Eight per cent of the calories of the Guatemalans came from fat, but fat supplied 40% of the calories of the larger group of U. S. urban males. Second, there is also a difference of 1000 calories. So the difference in fat is not the sole consideration. In addition, there is a big difference in the weights and in the estimated energy output of these individuals. The rural Guatemalans were mainly hard working citizens, tilling the soil, walking, not riding. Most of our U. S. urban population is not tilling the soil and is riding rather than walking.

There is quite a difference, as you probably have guessed, in the cholesterol levels of these groups. The rural Guatemalan male between 40 and 60 years of age has an average cholesterol level of 140 mg. per cent while the value for his urban American counterpart is almost 100 mg. per cent higher.

What did these people die from? We were interested in finding that out since a number of epidemiological type of studies in the literature suffer from a number of weaknesses, one of which is the fact that there is very little accurate information about the causes of death among the populations studied. That is, the cause of death is taken from hospital records. Even in the city of Chicago, to say nothing of rather out-of-the-way places, such records are notoriously inaccurate.

The degree of atherosclerosis associated with age was determined by some of my colleagues from

[a] Presented at the Symposium on Fats in Food, Eighteenth Annual Meeting of the Institute of Food Technologists, Chicago, May 29, 1958.

[b] See page 50, this issue.

slightly over 100 Guatemalan autopsies. This was expressed as a mean atherosclerosis index, an arbitrary system devised by Dr. Gore in our laboratory and Dr. Tejada of Guatemala to evaluate the extent and severity of atherosclerosis. When these Guatemalan data were compared with data supplied by Dr. Holman for people of a low-income group from New Orleans Charity Hospital, two facts became evident. First, there is little difference in the extent of atherosclerosis until the age of 25, and at the age of 25 there is a much sharper rise in the American data than in the Guatemalan data. The Guatemalan curve does not begin to rise until the age of 35 or 40, and it is not as steep. Parenthetically, it is of interest that most American males begin to gain weight appreciably at about 25 or 30 years. Secondly, from the New Orleans data, 51 cases of fatal heart attacks (fatal myocardial infarctions) were found in 316 autopsies of subjects over the age of 40, whereas in the Guatemalan data for the same age group only one case of myocardial infarction was observed in 234 autopsies.

A point which I believe people are beginning to realize more and more is that there is a difference in speaking of the prevalence of atherosclerosis and the incidence of coronary infarction, thromboses or heart attacks. Our thinking and talking have been a little lax as many of the so-called underdeveloped areas, or whatever you want to call them, are not entirely devoid of atherosclerosis. They do have atherosclerosis and a fair percentage of it, but there is a difference between the end results we are trying to avoid, i.e. the coronary thromboses leading to myocardial infarction.

The Guatemalan data emphasize that there are differences in the per cent of calories coming from fat, in body weight, in exercise, energy output, and in the degree of atherosclerosis. And there is marked difference in the prevalence of myocardial infarction.

NEAPOLITANS AND NEAPOLITAN BOSTONIANS, 2ND GENERATION

Because much of the data in the literature about atherosclerosis and serum cholesterol levels of Italians comes from the Naples area, we studied a group of second generation Italians living in Watertown, a suburb of Boston, whose parents came from Naples. The Hood Rubber Company, a large industrial plant in Watertown, employs a large number of Italians. Since their medical department is cooperative, and management is willing to give employees time off for interviews and examinations, we were able to find approximately 250 Italians whose parents came from the Naples area. Of these 250, 202 accepted our invitation to participate in the studies.

We refer to these people as Neapolitan Bostonians. We were interested in comparing information on them with data obtained by Dr. Keys and Dr. White, and others on first generation Neapolitans in Naples. The caloric intake of the Naples group was 3010, and our second generation Neapolitans had 3450 calories, with 13 and 14% of calories coming from proteins, respectively. There was quite a difference in the calories from fat. Fat supplied 20% of the calories in Naples and 43% of the calories for the second generation Neapolitans. What about the cholesterol levels of these people? The people from Naples do have a lower serum cholesterol than the second generation Neapolitan Bostonians. These values are 175 and 228 mg. per cent, respectively, for the 20 to 34 age group and 193 and 247 mg. per cent, respectively, for the 35 to 50 age group.

There are some interesting differences other than dietary components and serum cholesterol levels. One of these differences relates to body weight. In the Boston group some individuals are skinny, others are just a little bit overweight, and others are really quite plump.

BEING OVERWEIGHT VERSUS BECOMING OVERWEIGHT

The average cholesterol level of the skinny people was 223. Those who were moderately overweight, and who in many cases were in the process of becoming really overweight, had a higher cholesterol of 243, and those who were really overweight had a value of 232. There is no difference between the first and last figures, but those people who were in the process of getting fat have distinctly higher cholesterol levels than the skinny individuals. The data point to a trend which we have recently observed in people, and also in animals. That is, the hazards, whatever they are, are not as great in *being* overweight as they are in *becoming* overweight.

The data on the blood pressure of these Neapolitan Bostonians are also interesting. Those people who had normal blood pressures averaged cholesterol levels of 233. Those who had borderline pressures averaged 252, and those who had definitely high blood pressures averaged 260.

Another thing that comes into the picture of most types of cardio-vascular diseases is heredity. When our 200 people were classified into two groups, those who had a strong family history of cardio-vascular disease and those who did not, the people without any family history of this disease tended to have lower serum cholesterols than the people who had a positive history. This study was done 2 years ago. We are now repeating the study on the same 200 people, and I think that it will show that factors other than the caloric and fat contents of the diet are involved.

FOUR YOUNG MEN

Now I would like to refer briefly to data which are in line with what Dr. Stamler referred to when he spoke of the geese that were stuffed with carbohydrates. This study involved 4 young men. One young man, 27 or 28 years of age, had a cholesterol level of 125 after being on a diet of 3,000 calories containing less than 15 g. of fat and less than 50 mg. of cholesterol for a period of one month. He was then stuffed with carbohydrates (to the extent of 2,000 calories of extra carbohydrates) for another month. He gained 11 pounds and his cholesterol went from 125 to 200 mg. per cent. In the third month, he lost 8 pounds

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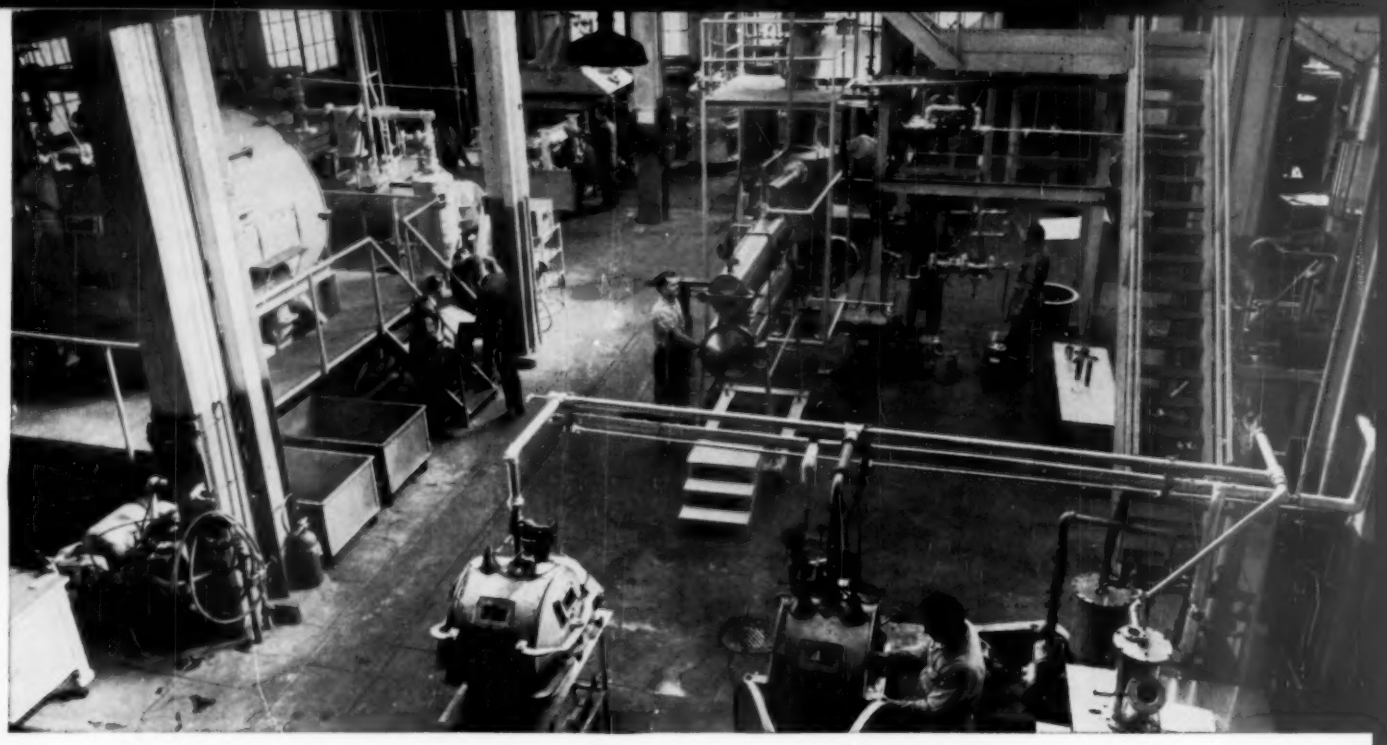

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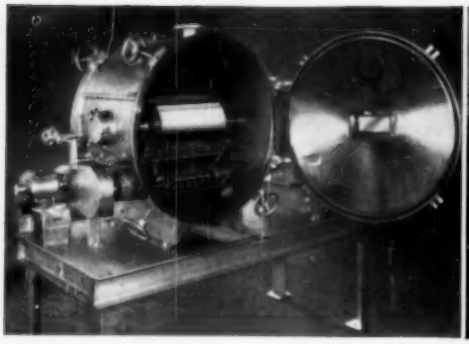

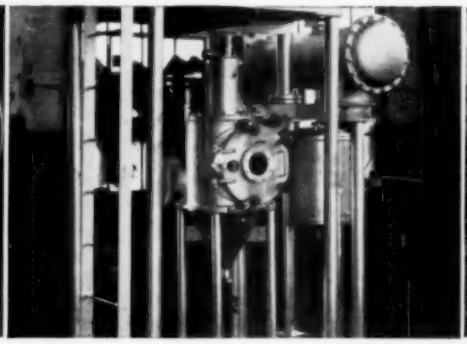

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and his cholesterol began to fall. Serum lipoproteins usually precede changes in cholesterol, and during this third month his beta lipoproteins fractions were reduced from 250 to 75 mg. per cent. This study shows that a rapid gain in weight, even when the calories come from carbohydrates and not fat, is accompanied by an increase in serum cholesterol.

In a similar study, an individual was on a diet which contained 175 g. of fat instead of 15. In addition, the diet contained 1000 mg. of cholesterol, not 50 or less. His weight at the beginning was 196 pounds and his cholesterol level was 155 mg. per cent. For a period of a month, he increased his calories to 6,200, a tremendous increase, but he kept his weight almost the same through vigorous exercise (7 or 8 hours of hard physical exercise a day). He put on only four pounds during this month, despite this large intake of calories and fat, yet there was no increase in serum cholesterol. During the third month, he consumed 5400 calories, which is still quite a bit, but he had no exercise other than his habitual activity before the study. He gained 14 pounds and his cholesterol level went up from 165 to 275. To get rid of some of this fat, he went on a diet of 2300 calories and lost 8 pounds. At the end of this period, his cholesterol was on its way down, even with an intake of 175 g. of fat. Thus, as long as the fellow did not gain weight, there was no change in the cholesterol level. Both of the previous studies were done a few years ago by Dr. George Mann when he was associated with us.

PROTEIN IS INVOLVED

An experiment with monkeys shows us that the protein content of the diet can also affect cholesterol levels. When the protein of the diet was raised from 10% to 25%, and changed from a methionine deficient protein to a good quality protein (casein), the cholesterol level fell from 600 to 300. The only dietary difference was in protein; the first diet had a lower amount of poor quality protein and the second one had a higher amount of good quality protein. The same amount of cholesterol and fat was used in both periods.

Data obtained with rats by one of my associates, Dr. Fillios, emphasizes the effect of dietary protein in the degree of cardio-vascular sudanophillia (an indication of the degree of early atherosclerosis). Data for cholesterol are similar to the monkey studies I have just mentioned. When there is 10 and 20% casein in the diet, there is very little difference in the cholesterol level or the degree of atherosclerosis. But at a lower protein level, 5% casein, there is quite an increase; and, interestingly enough, at very high levels of casein intake (40 to 60%) there is also an increase in the hypercholesteremia.

From our experimental studies, we feel quite convinced that protein is involved in the establishment of serum cholesterol levels in rats, and that high cholesterol values are favored by either very low or very high protein diets. We have also found a difference in cholesterol level depending upon whether starch or sucrose is the main carbohydrate in the experimental diet of the rat.

FIVE POINTS

Five points on which, I think, there is good evidence, are involved somehow in the picture of atherosclerosis and coronary artery disease. These are:

1. Heredity
2. Overweight
3. Blood cholesterel
4. Blood pressure
5. Excessive smoking

These are all predisposing factors. There is no question whatsoever about heredity, and there is not a physician in the country who would stand up and say that heredity is not involved in this condition. It is involved. Likewise, overweight, increased blood cholesterol, increased blood pressure, and excessive cigarette smoking are involved.

Stress and strain? There is no evidence that I know of that hard physical work is involved; in fact, there is evidence to the contrary, that people who are in sedentary occupations are much more apt to develop this disease than people who are in occupations requiring physical activity. There is little evidence that stress factors are involved although a paper from San Francisco in the current issue of *Circulation* makes such a claim. This study is on the cholesterol levels of public accountants from January 1 to about July 1; it points out that their cholesterol goes up as April 15 approaches! While it is only one paper, it is very interesting reading. I know the author. He is a good man. But it is awfully difficult for me to believe it. Everything fits too well. Stress and strain have not been studied too much; they are difficult to evaluate. You cannot think of stress and strain except in terms of an individual. What may be stress and strain for me may not be for you, and vice versa. I think most of us will agree that John Foster Dulles leads a life full of stress and strain. Physically, he goes all around the world and psychologically and mentally, he must face great decisions every day. I made this remark once and went on to say that it has not affected his heart, but someone from the audience called out "What about his head?"

This leads me to make a statement that Dr. Stamler almost made. That is, coronary artery disease and cerebral hemorrhage and stroke are the same for all practical purposes. One is atherosclerosis of the vessels of the heart and the other is atherosclerosis of the vessels of the brain, and the two of them are certainly most important public health problems. Obviously, diet and nutrition come into the problems of overweight, cholesterol level and, to some extent, blood pressure.

IN THREE OF THE FIVE, DIET IS INVOLVED

In the last couple of years, there have been a few studies which have indicated that the above 5 points seem to be involved in this condition in an additive fashion, although one may be of more importance to an individual and of less importance to another. So, if you are a person who has all 5 things (if you have a strong family history of cardiovascular disease and you are overweight and have an elevated cholesterol,

etc.) then you are really behind the eight ball. On the other hand, if you have only four of these things, you're not as badly off as if you had all five. If you have only two, you're beginning to get on the lucky side. The point is, these things are additive.

You and I cannot do anything about our heredity; we cannot change our parents. The other factors are the ones which you can do something about, if you are sufficiently motivated. And diet, somehow or other, is involved in three of them.

The Storage Stability of Freeze-Dried Soup Mixes*

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DETERIORATION of dehydrated vegetables has been characterized by the development of off-flavors and the loss of color. In some processes of dehydration the green vegetables develop off-flavors reminiscent of hay during processing *(5)*. This effect is greatly accelerated during storage, particularly if the storage atmosphere contains oxygen. Flavors produced under such conditions are accompanied by a progressive decrease in the green color. Vegetables which contain high concentrations of carotenoids, such as carrots and tomatoes, develop perfume-like odors and flavors during storage *(5)*. This effect also has as its companion the loss of color, although in carrots there is also an extensive oxidation of the carrot oils.

When dehydrated vegetables are used as ingredients of dried soup mixes, the storage stability of the soup mix is a function, to a large measure, of the vegetables. Freeze-dried vegetables possess an important advantage over dehydrated vegetables in that they rehydrate at a more rapid rate and may even be rehydrated in cold water in a reasonable length of time *(2)*. The storage stability of freeze-dried vegetables under oxygen-containing atmospheres may not be superior to those dehydrated conventionally, although fruit which has been dried by sublimation is vastly more resistant to storage destruction than conventionally dried fruit *(1)*. In an investigation of freeze-dried carrots, Mackinney, Lukton, and Greenbaum *(3)* found freeze-dried carrots to be less stable under various storage conditions than conventionally dried carrots. Thus, a soup mix prepared from freeze-dried vegetables could be expected to be more readily rehydratable than one from prepared dehydrated materials, but its storage stability is questionable. In order to determine the relative merits of freeze-dried mixes, their stability during storage was measured by a flavor panel and compared to identical soup mixes prepared from commercially dried vegetables.

EXPERIMENTAL PROCEDURE

Commercially dried vegetables. Commercially dehydrated diced carrots, potatoes, tomatoes, celery, spinach, and leek were purchased and held at 32° F. until used (approximately 3 weeks). The moisture content of these vegetables was determined by the vacuum oven method (Table 1). The rehydration rate was measured by a modification of Spinella's method *(4)*. A weighed quantity of vegetables was added to boiling water and the suspension was filtered at various intervals upon a Buchner funnel. The vegetables were allowed to remain on the filter under vacuum for approximately 2 minutes, then removed to a moisture dish and the moisture content determined conventionally in duplicate. The rehydration curves for the dehydrated vegetables are given in Figure 1.

TABLE 1

Moisture content of commercially dehydrated vegetables

Vegetable	Percent moisture
Spinach	6.43
Potatoes	6.54
Celery	4.65
Tomatoes	5.16
Parsley	2.21
Carrots	2.89
Leek	2.37

* Presented at the Eighteenth Annual Meeting of the Institute of Food Technologists, Chicago, May 28, 1958.

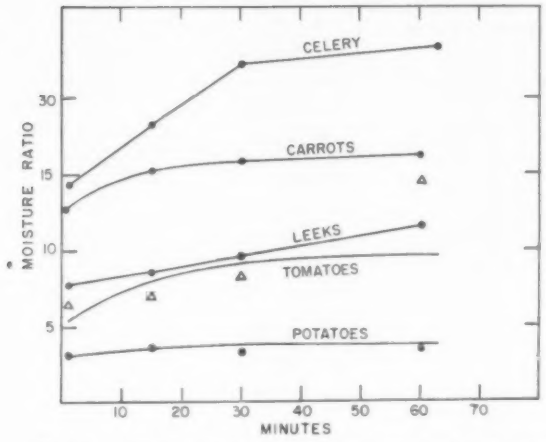

Figure 1. Rate of rehydration in cold water of freeze-dried vegetables. (moisture ratio = weight of moisture per unit weight of dry matter)

Freeze-dried vegetables. Fresh vegetables were processed immediately after purchase at a local market. After sorting, washing and trimming, the potatoes, carrots, and tomatoes were peeled. The potatoes were diced to approximately ½ inch square; the tomatoes and spinach, chopped; carrots and leeks, flaked. The potatoes, carrots and celery were blanched at 210° F. for 7, 3, and 1 minute, respectively. Immediately after these pre-treatments, the individual vegetables were frozen on stainless steel trays, placed on the heated shelves of a Stokes freeze-dryer and subjected to a vacuum of approximately 350 μ of mercury. The heating shelves were held at 40° C. for the entire drying period. The initial moisture content of each vegetable was determined by the vacuum oven method. The rate of water evaporation was measured by removing the trays containing the vegetables at various time intervals to determine the weight loss. Figure 2 presents the rate of evaporation for the various vegetables. Table 2 gives the initial and final moisture content of the vegetables used in the freeze-drying experiments.

Vegetables were stored in the dark at 32° F. under nitrogen until the soup mixes were prepared. Rehydration tests were performed on the freeze-dried vegetables in both cold and boiling water. Tomatoes and potatoes rehydrated readily, but lost their structure rapidly in boiling water. The erratic rehydration curves for tomatoes and potatoes are traceable to this difficulty. Figure 3 shows the rehydration curves for freeze-dried vegetables in cold water and Figure 1, the rehydration curves of both the freeze-dried and dehydrated vegetables in boiling water. Table 3 gives the moisture content of both the freeze-dried and the dehydrated vegetables after rehydration to equilibrium moisture content in boiling water.

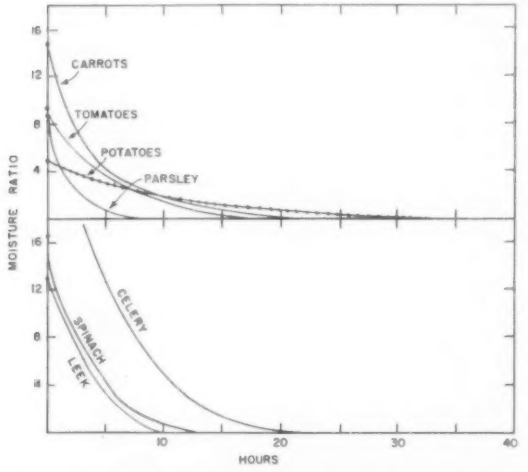

Figure 2. Rate of water loss during freeze drying. (moisture ratio = weight of moisture per unit weight of dry matter)

TABLE 2

Initial and final moisture content of freeze-dried vegetables

Vegetable	Initial moisture	Final moisture
Carrots	93.7	2.24
Celery	96.3	2.37
Parsley	89.8	2.10
Leek	92.9	1.53
Spinach	94.3	1.17
Tomatoes	90.4	3.76
Potatoes	83.4	1.84

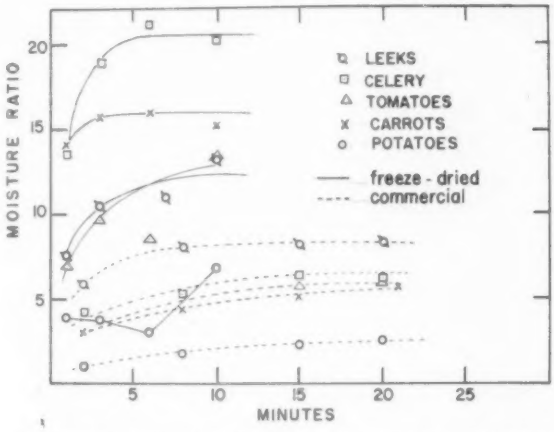

Figure 3. Rate of rehydration of freeze-dried and dehydrated vegetables in boiling water. (moisture ratio = weight of moisture per unit weight of dry matter)

TABLE 3

Moisture contents of rehydrated[1] freeze-dried and commercially dehydrated vegetables

Vegetable	Freeze-dried		Dehydrated	
	Rehydration time	Moisture	Rehydration time	Moisture
	(minutes)	*(%)*	*(minutes)*	*(%)*
Carrots	1	93.4	21	85.0
Celery	3	95.0	15	86.6
Leek	3	92.0	8	89.0
Tomatoes	3	90.7	20	85.9
Potatoes	10	85.4	20	71.7

[1] Rehydration in boiling water.

Soup mixes. In Table 4 the percentages of each of the components used in making the soup mixes are listed. An equal amount (2,250 g.) of soup mix was prepared using dehydrated vegetables in one case and freeze-dried in the other. After preparation, each of the mixes was subdivided into 10 lots (approximately 180 g. each) and packed in glass containers.

TABLE 4

Soup mix components on a dry weight basis

	(%)
Salt, pepper, garlic and onion powder, spices	18.0
Meat extract	1.5
Corn starch	21.7
Glutamate	8.8
Hydrogenated vegetable fat	14.2
Vegetable:	
Leek	5.8
Carrots	3.6
Celery	7.0
Spinach	1.3
Parsley	1.5
Potato	13.3
Tomato	3.3

Storage. Six samples of each preparation were stored at 100° F., three in a nitrogen atmosphere and three in air. Three portions of each preparation were also stored under nitrogen at 32° F.

The tenth sample of each mixture was evaluated immediately following the preparation of the soup mixes. The storage samples were evaluated each month of a 3-month storage period.

Testing. Eight judges from among the Food Technology staff volunteered to participate in the training program. They were trained for 6 weeks, with 3 sessions a week, to develop an ability to detect off-flavors in dehydrated commercial vegetable soup mixes. Variations in off-flavor intensity of the commercial soup mixes were obtained by storing the samples at high temperatures for varying lengths of time.

The score sheet used for both panel training and judging of the experimental samples included the following questions: (1) designation of type of off-flavor, (2) intensity of off-flavor (0 = none to 5 = intense) (3) designation of quality level (good, fair, poor).

Six of the 8 judges were retained to evaluate the experimental soups. The other 2 judges were eliminated because of inconsistency of scoring and/or inability to detect off-flavors.

Preparation of sample for testing. Dried soups were prepared for tasting by adding 620 ml. of boiling water to 36 g. of soup mix. Freeze-dried soup mixes were simmered for 7 minutes, and the dehydrated mixtures for 10 minutes. After 7 minutes the freeze-dried material was completely rehydrated, and after 10 minutes the dehydrated vegetables were substantially rehydrated. The soups were cooled to 60° C. and maintained at this temperature throughout the half-hour tasting session. They were served to panel members in coded, black-lined sauce dishes under red illumination.

A balanced incomplete block design was applied in order to limit the number of samples tasted at one time to three. The serving order was completely random among the panel. Four sessions were required for the initial evaluation and ten sessions to complete the design at each storage period. The testing was completed in five days of the same week, with sessions at 11:30 a.m. and 3:00 p.m. each day.

RESULTS AND DISCUSSION

Figures 1 and 3 illustrate the ready rehydratability of the freeze-dried vegetables when compared with dehydrated. It is to be noted that dehydrated vegetables, even after prolonged boiling, do not reach the moisture content of the fresh material (Table 3), whereas the freeze-dried vegetables achieve this moisture content in cold water in approximately 30 minutes. In boiling water the freeze-dried material is essentially rehydrated in 4 minutes.

After prolonged storage, particularly under oxygen, the carotenoid pigments in freeze-dried vegetables bleached badly; the dehydrated vegetables, on the other hand, retained their color to a much larger extent. This effect has been noted previously by Mackinney *et al. (3)* in freeze-dried carrots. It has been assumed that the porosity of freeze-dried material allows a more ready interchange of oxygen, and the large surface area promotes oxidative reactions, causing a more rapid bleaching in the puffed material than in the shriveled dehydrated vegetables.

Results of the panel evaluation, after the initial and subsequent storage periods, are presented in Figure 4. Several judges commented as to the lack

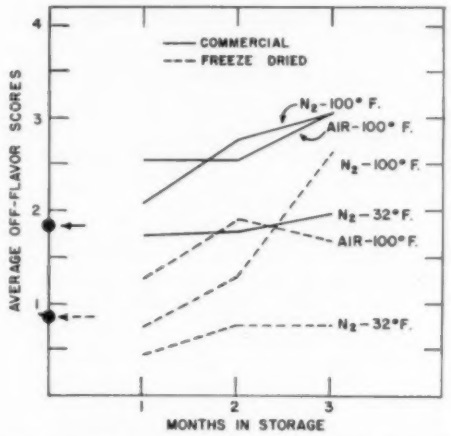

Figure 4. Off-flavor intensity development in soup mixes during storage.

of flavor and hay-like flavor of the dehydrated soup. This probably accounts for the high off-flavor scores of this soup at the initial evaluation. After 1 month's storage, there was a significant difference among the samples due to both temperature and atmosphere of storage (Table 5). The effect of these 2 factors was the same in both types of soup. Those packed under nitrogen and stored at 32° F. were less affected by storage time than those stored under nitrogen at 100° F. Samples stored under air definitely developed more off-flavor.

As the storage time lengthened the protective effect of nitrogen lessened. At 2 months, in the case of the dehydrated vegetables, and at 3 months, in the case of the freeze-dried, the nitrogen packs at 100° F. actually were designated as more off-flavored. A possible explanation of this phenomenon might be that the nitrogen, while containing some oxygen, slowed the oxidation steps but also prevented the completion of some of the steps. This would lead to the accumulation of undesirable flavors which might have been partially destroyed in the more highly oxygenated packs.

This phenomenon is borne out by the statistical analysis of the off-flavor scores in each of the storage periods (Table 5). As time progressed, the atmosphere effect became insignificant, whereas the effect of storage temperature was enhanced with time. The

TABLE 5

Table of analysis of variance of off-flavor scores

Month	Source of variation	DF	SS	MS	F ratio
1	Dehydration	1	10.6463	10.6463	12.9517**
	Temperature	1	6.4288	6.4288	7.8209**
	Atmosphere	1	3.4151	3.4151	4.1546*
	Dehydration x temperature	1	0.2992	0.2992	0.3640
	Dehydration x atmosphere	1	0.5077	0.5077	0.6176
	Error	35	28.7717	0.8220	.....
	Total	40			
2	Dehydration	1	5.5370	5.5370	12.1692**
	Temperature	1	3.1397	3.1397	6.9004*
	Atmosphere	1	3.9693	3.9693	8.7237**
	Dehydration x temperature	1	1.8887	1.8887	4.1510*
	Dehydration x atmosphere	1	12.2641	12.2641	35.9982***
	Error	36	16.3782	0.4550	.....
	Total	41			
3	Dehydration	1	10.8834	10.8834	12.1304**
	Temperature	1	14.2272	14.2272	15.8573***
	Atmosphere	1	0.6052	0.6052	0.6745
	Dehydration x temperature	1	0.1876	0.1876	0.2090
	Dehydration x atmosphere	1	0.8541	0.8541	0.9520
	Error	36	32.3007	0.8972	.....
	Total	41			

* Significant at .05 probability level.
** Significant at .01 probability level.
*** Significant at .001 probability level.

TABLE 6

Off-flavor frequency from 30 judgments per storage period

	Rancid	Perfume	Stale	Hay	Fish	Old	Scorched	Oily	Bitter
Initial									
F.D.[1]	3	....	2	1	....	....	1	....	....
D.[2]	1	....	2	2	....	....	1	3	....
1 Month									
F.D. N_2 @ 32° F	2	....	4	3	....	....	....	....	....
F.D. N_2 @ 100° F	1	2	5	2	1	1	1	....	....
F.D. Air @ 100° F	6	5	5	3	....	....	3	....	1
D. N_2 @ 32° F	4	....	9	9	2	....	1	3	....
D. N_2 @ 100° F	8	1	13	14	2	....	7	....	2
D. Air @ 100° F	6	....	16	13	4	....	6	....	....
2 Months									
F.D. N_2 @ 32° F	4	1	5	4	....	....	....	....	....
F.D. N_2 @ 100° F	7	....	14	5	....	....	2	....	3
F.D. Air @ 100° F	12	2	11	5	....	....	3	....	1
D. N_2 @ 32° F	6	1	13	8	....	....	4	....	1
D. N_2 @ 100° F	11	1	14	10	....	....	10	....	....
D. Air @ 100° F	13	1	16	12	....	....	8	....	1
3 Months									
F.D. N_2 @ 32° F	6	2	6	....	....	....	0	....	....
F.D. N_2 @ 100° F	16	5	9	8	....	....	4	....	....
F.D. Air @ 100° F	12	3	9	10	....	....	2	....	1
D. N_2 @ 32° F	8	2	7	11	....	....	4	....	....
D. N_2 @ 100° F	6	2	10	11	....	....	10	....	....
D. Air @ 100° F	5	1	11	13	....	....	15	....	....

[1] F.D. = Freeze-dried.
[2] D. = Dehydrated.

TABLE 7

Flavor quality designations after each storage period, showing percent of responses

Months in storage	Flavor quality	F.D.[1] N_2 32° 1	F.D. N_2 100° 2	F.D. Air 100° 3	D.[2] N_2 32° 4	D. N_2 100° 5	D. Air 100° 6
1	Good	76.9	75.0	33.3	28.0	17.2	10.3
	Fair	23.1	25.0	48.2	64.0	55.2	55.2
	Poor	0.0	0.0	18.5	8.0	27.6	34.5
2	Good	73.3	37.9	24.1	33.3	20.7	17.2
	Fair	23.3	44.8	48.3	50.0	27.6	34.5
	Poor	3.4	17.3	27.6	16.7	51.7	48.3
3	Good	63.6	9.4	30.3	16.7	13.8	6.5
	Fair	30.3	50.0	45.5	70.0	31.0	35.5
	Poor	6.1	40.6	24.2	13.3	55.2	58.0

[1] F.D. = Freeze-dried.
[2] D. = Dehydrated.

initial difference in flavor between the two types of soup was apparent throughout the investigation. An analysis of the effect of storage time on off-flavor development was statistically significant at the .01 level and the effect was the same for both types.

Table 6 shows the frequencies with which the panel attributed specific types of off-flavors at each storage period. The number of reactions toward a rancid flavor in the freeze-dried samples increased with increased storage time. This was not as clearly defined in the dehydrated types; probably because the hay and stale flavors were so predominant. A scorched flavor became more apparent with time in the dehydrated mixtures, especially at the higher temperature.

Overall quality designations are summarized for each evaluation period in Table 7. For practically all samples the decreasing good and increasing poor quality responses were apparent from one period to the next.

SUMMARY

The relative storage stability of freeze-dried soup mixes *vs.* dehydrated soup mixes was determined by a sensory panel. Freshly prepared soup mixes made from freeze-dried vegetables were judged higher in quality with less off-flavor than those prepared from dehydrated vegetables. The effect of storage at elevated temperatures increased the off-flavor scores of both types of mixes similarly. Initial flavor differences were maintained throughout the three-month storage period. The effect of packing under nitrogen was to first decrease the off-flavor scores, but as storage time progressed the effect was reversed.

Dehydration rates of freeze-drying for various vegetables are presented. Rehydration rates were significantly faster and the water uptake ratios were higher for freeze-dried than for conventionally dehydrated vegetables.

Acknowledgment

The senior author expresses his appreciation to the Nestlé Company, which made this work possible.

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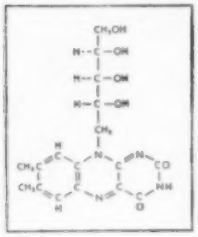
The Vital Story

A Quick History. Independent investigators, working separately to unlock several of nature's doors, sometimes open up unsuspected relationships. This happened with vitamin B_2.

Investigations. About 25 years ago, several groups, notably Warburg's, were investigating a "yellow enzyme" obtained from yeast. Almost simultaneously other investigators were studying a food factor that aided growth of laboratory animals.

What they found. Proceeding with chemical analysis of this growth factor, the team of Kuhn, György, and Wagner-Jauregg noted a relationship between the growth-producing agent and the "yellow enzyme." Their findings, and those of other researchers along similar lines, were published in 1933. Eventually, riboflavin and an essential part of the yellow enzyme were found to be identical and the unity of an essential nutrient and cellular metabolism was established.



Isolation of pure riboflavin was achieved by Kuhn and his co-workers, and by Ellinger and Koschara, in 1933.

Nomenclature. Known in the United States as riboflavin, this vitamin has also been called lactoflavin, ovoflavin, hepatoflavin, and vitamin G.

SYNTHESIS

By 1935, two eminent chemists, working separately, had synthesized riboflavin, practically in a dead heat. Prof. Paul Karrer of the University of Zurich, a collaborator of the Hoffmann-La Roche Laboratories, produced the first successful synthesis. Five weeks later Richard Kuhn of Germany announced his synthesis of the vitamin. Prof. Karrer subsequently shared the Nobel Prize in Chemistry for his work in vitamins and carotenoids.

The Karrer synthesis forms the basis for chemical processes in widespread use today by Hoffmann-La Roche and other leading manufacturers throughout the world. Riboflavin is also manufactured today by fermentation methods.

CHEMICAL AND PHYSICAL PROPERTIES

Riboflavin is yellow, slightly water-soluble with a greenish fluorescence and a bitter taste. Its empirical formula is $C_{17}H_{20}N_4O_6$. Vitamin B_2 produced by the Roche process is identical in every way with that occurring in nature.

How does vitamin B_2 work? Riboflavin is a vital part of nature's chain of reactions for utilization of carbohydrate energy. It has been found to be a constituent of many enzyme systems and is thus intimately connected with life processes. It is probably required by the metabolic processes of every animal and bird as well as by many fishes, insects and lower forms of life. (In certain animals, however, the requirement may be synthesized by bacteria within the intestine.)

In the cells riboflavin goes to work attached to a phosphate group. This substance, known as riboflavin-5'-phosphate or flavin mononucleotide, may in turn be attached to still another essential substance, adenylic acid, forming flavin adenine dinucleotide. Either nucleotide then is attached to protein, thereby forming an enzyme, and takes its part in oxidation-reduction reactions.

Requirements in Human Nutrition. As we have seen, vitamin B_2 is essential to life. We have no special storage organs in our bodies for this vitamin, although a certain level is maintained in various tissues, with relatively large amounts found in the liver and kidneys.

MEASURING METHODS

In the beginning, riboflavin activity was described in "Bourquin-Sherman units" and requirements were thought to be very small. Subsequent research showed otherwise. Milligrams of weight became the unit and the Food & Drug Administration of the U. S. Dept. of Health, Education & Welfare established (July 1, 1958) a minimum daily requirement of 1.2 mg. of riboflavin for all persons 12 or more years old. For infants it is 0.6 mg. These requirements are designed to prevent the occurrence of symptoms of riboflavin deficiency disease. The minimum daily requirement for this vitamin for children from 1 to 12 years is 0.9 milligram.

Recommended allowances. The Food & Nutrition Board of the National Academy of Sciences—National Research Council, in its 1958 publication #589, recommends the following daily dietary allowances of riboflavin, expressed as milligrams. These are designed to maintain good nutrition of healthy persons in the U.S.A.

Men	1.8	
Women	1.5	
Women (pregnant; second half)	2.0	
Women (lactating)	2.5	
Infants (2 to 6 months)	0.5	
Infants (7 to 12 months)	0.8	
Children (1 to 3 years)	1.0	
Children (4 to 6 years)	1.3	
Children (7 to 9 years)	1.5	
Children (10 to 12 years)	1.8	
	Boys	*Girls*
Adolescents (13 to 15 years)	2.1	2.0
Adolescents (16 to 19 years)	2.5	1.9

# of VITAMIN B_2

(Riboflavin)

by Science Writer

Deficiencies of vitamin B_2 appear in several ways in human beings. The eyes, the skin, the nerves, and the blood show the effects of too little riboflavin. Laboratory animals have demonstrated that a riboflavin-deficient diet can cause death of adults and can slow or stop growth in the young. Female animals, deprived of riboflavin in the diet, may produce offspring with congenital malformations.

Medical uses. To overcome and control deficiencies in human beings, physicians have pure riboflavin available for administration by injection or orally, by itself or with other "B" vitamins or multi-vitamin-mineral combinations.

How do we get our daily riboflavin? Vitamin B_2 has wide distribution throughout the entire animal and vegetable kingdoms. Good sources are milk and its products, eggs, meats, legumes, green leaves and buds. Whole-grain cereals have significant but not large amounts of riboflavin.

ADDITION TO FOODS

Cereal foods play a large part in our diet. To produce the white flour almost all of us want, millers are obliged to remove parts of the wheat that contain much of the grain's riboflavin and other nutrients. In addition, cereal grains are not rich sources of riboflavin. Millers meet this problem by *enriching* the grain foods for which federal standards exist with vitamins B_1, B_2, niacin and the mineral iron. In the case of vitamin B_2, however, they do more than *restore* the processed food to its natural riboflavin level; they *fortify* the food with enough of this essential vitamin to make it nutritionally more valuable than it was in nature.

Acting to protect the good health of millions of Americans, bakers and millers adopted *enrichment* of white bread and white flour in 1941. Since that time, other foods, such as macaroni products, corn meal and grits, farina, pastina and breakfast cereals have had their food value increased by enrichment with pure riboflavin and other vitamins and minerals.

When enriching, fortifying or restoring, food manufacturers add the necessary quantity of riboflavin (and other vitamins and minerals) to the food during processing, so that the finished product meets federal, state, and territorial requirements or contributes to the consumer an amount of the vitamin that dietary experts believe significantly useful.

PRODUCTION

Prof. Karrer's synthesis of riboflavin was a laboratory success. Adapting the process to commercial production, however, demanded original thinking by chemists at Hoffmann-La Roche. The production of riboflavin by chemical synthesis requires the production of ribose, a rare sugar, at an early stage in the process. This special sugar must be made inexpensively if the synthesis is to be practical. Sugar chemistry is a difficult matter. In a brilliant piece of work, the Roche chemical experts developed a method to produce ribose on a commercial scale by an electrolytic process, thus overcoming a most troublesome problem. Subsequently, Roche chemists developed the first practical synthesis for riboflavin-5′-phosphate, identical with natural flavin mononucleotide.

Picture three streams joining to form a river and you have a simplified idea of the Roche process for synthesizing vitamin B_2. O-xylene and glucose are processed separately to form xylidine and ribose respectively. These are joined to form ribitylxylidine, which is then converted to ribitylaminoxylidine. Starting separately with malonic ester, which is processed through intermediate stages to alloxan, the third "stream" is then joined with ribitylaminoxylidine to form riboflavin. Purification occurs at each step of the synthesis. Riboflavin Roche* equals or exceeds U. S. P. standards.

By the tons. So efficient is the Roche process that pure riboflavin is produced *by the tons* for use in pharmaceutical products and processed foods. An interesting development by Roche is the production of riboflavin in different forms related to the method of end use. Roche* Regular riboflavin U. S. P. is especially useful in dry enrichment premixes, powdered dietary supplements, pharmaceutical tablets and soft gelatin capsules. Roche* Solutions type is preferred for the manufacture of solutions having low concentration. Roche* Riboflavin-5′-Phosphate Sodium is a highly and rapidly soluble riboflavin compound favored for all pharmaceutical liquid products and some tablets, lozenges, and capsules. It has a more pleasant taste than the bitter U. S. P. riboflavin.

This article is published in the interests of pharmaceutical manufacturers, and of food processors who make their good foods better using pure riboflavin Roche.* Reprints of this and others in the series will be supplied on request without charge. Also available without cost is a brochure describing the enrichment or fortification of cereal grain products with essential vitamins and minerals. These articles and the brochure have been found most helpful as sources of accurate information in brief form. Teachers especially find them useful in education. Regardless of your occupation, feel free to write for them. Vitamin Division, Hoffmann-La Roche Inc., Nutley 10, New Jersey. In Canada: Hoffmann-La Roche Ltd., 1956 Bourdon St., St. Laurent, P. Q.

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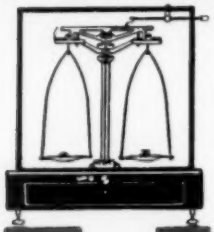

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Processing of Food Fats — A Review*

J. H. Sanders

The Procter and Gamble Co., Ivorydale, Ohio

(Manuscript received June 19, 1958)

THE ECONOMIC BASIS for the existence of the many food fats processing plants in our country and abroad is well known. The number and the complexity of these food fats processing plants are of high magnitude, because most natural fats at their source fail to meet the food quality standards that are wanted, and can be afforded, by people in the well-developed countries of the world. It is worthwhile to review the various quality problems involved, and the way they are handled by the processors of food fats.

QUALITY REASONS FOR PROCESSING

As every farm boy knows, butter-fat properly separated from the fresh milk of healthy, well-fed cows, needs only a little "ripening" and churning to yield the delectable "country butter" enjoyed by the rural population of our dairy states. This on-the-farm ripening is an uncontrolled bacterial fermentation of citrates in the milk to form the flavorsome and odorous compound diacetyl. Such fermentations—some good and some not good—are taking place in the butter-fat that is held and delivered to commercial creameries. Special processes are needed to counteract the effects of the unwanted fermentations, and to produce good and stable butter for broad distribution to the market.

Separation of lard from the hog is more involved—at least to most people—than separation of milk from the cow. In the lard recovery process—the rendering process—the fatty-tissue from the slaughtered hog is heated, wet or dry, until fat melts away from tissue. Because of the nature of the treatment, admixture with some protein matter is unavoidable. Also, during rendering some of the fat hydrolyzes, giving varying amounts of free fatty acids, and other by-products.

Just as the crude animal fats contain varying amounts of non-fat constituents, so also do the crude vegetable oils. Since the vegetable oil is extracted from a seed, and since the seed is a storehouse of life-sustaining foods intended for the next plant generation, the crude vegetable oils, in general, contain an even greater variety and amount of minor constituents. The principal minor constituents and some typical percentages in good grade crude soya bean oil, in crude lard, and in crude butter-fat are shown in Figure 1.

Fats and oils are important sources of the oil soluble vitamins A, D, E, and K. Apart from their nutritional significance, these vitamins may impart characteristic color, and/or anti-oxidant properties, to the oils containing them. The yellow color in butter is due in part to carotenoids associated with Vitamin A; and the stability against oxidation of vegetable oils is due in part to the presence of the anti-oxidant alpha-tocopherol (Vitamin E), present at 0.17% in soya oil.

	SOME TYPICAL VALUES		
	% IN CRUDE SOYA BEAN OIL	% IN CRUDE LARD	% IN CRUDE BUTTER FAT
FREE FATTY ACIDS (AS OLEIC)	0.5	2.5	5 (LACTIC)
PHOSPHOLIPIDS	1.5	.02	2.0
STEROLS	.4	.11	.36
HYDROCARBONS	.20	—	—
COLOR BODIES	.004	—	.0006
TOCOPHEROL (VITAMIN E)	.17	.002	.003
VITAMINS A, D, K	—	—	—
WAXES	.002	—	—
PROTEINS	—	—	—
CARBOHYDRATES	—	—	—

Figure 1. Principal minor constituents in crude fats and oils.

Although workers in crude vegetable oil mills have been seen dunking their lunch bread into freshly produced crude vegetable oil, and eating that bread with obvious satisfaction, nevertheless our domestic crude vegetable oils require considerable processing for general acceptance. Processes practiced in modern food fat plants do indeed remove virtually all of the color, odor, and flavor-compounds from the crude vegetable oils.

Principal constituents of fats and oils, of course, are the triglycerides, or mixtures of triglycerides with small quantities of mono- or diglycerides. A triglyceride is a combination of the trihydric alcohol, glycerine, and 3 fatty acids of different or identical character. The glycerine portion does not vary among the triglycerides, but there is considerable variation in the structure of the fatty acid side chains, and the location of these fatty acids on the 3 available positions of glycerine. One such variation is chain length—the longer chains imparting higher melting point to the triglyceride—and another is degree of unsaturation, the lower levels imparting both higher melting point and greater oxidative stability.

The *cis* form of the unsaturated acids occurs generally in natural oils. Trans-isomers are generated in hydrogenation, and because of their higher melting points, limit the amount of hydrogenation that can be applied against improved keeping quality.

The relative positions of the 3 component acids have a pronounced effect on the properties of the fat. By special means, the fat processor can make some changes in these relative positions and thus build into the fat especially desired properties. Since Mother Nature had in mind her own uses for the naturally occurring fats and oils and did not balance their properties to suit the "whims" of any group of men, it is up to the food fat processors to make such changes in the natural fats as are needed to conform

*Presented at the Symposium on Fats in Food at the Eighteenth Annual Meeting of the Institute of Food Technologists, Chicago, May 29, 1958.

to our pattern of marketing, of end-use, and of palatability standards.

THE CONVENTIONAL PROCESS STEPS

Butter and margarine are very important food fats throughout the world. The technology of making them is generally known. For this reason, and for the reason that the available space might preferably be used on the less familiar processes, the technology of these fat spreads will not be covered here.

The over-all process sequence usually followed in transforming crude vegetable oils into finished products includes (1) storage, (2) alkali refining, (3) water washing and drying, (4) bleaching, (5) hydrogenating, (6) formula blending, (7) deodorizing, (8) polishing (filtration), (9) plasticizing and packaging, and (10) tempering. Unit operations can, of course, be used in a variety of combinations, and applied to animal, marine, or vegetable oils.

Good storage conditions, assuring clean dry crude oil at minimum practicable temperatures and with minimum air exposure, do much to preserve the oils. The first process step, however, is that of alkali refining.

Alkali refining. There are in use batch or "kettle" methods for refining. However, economy, in general, dictates the use of centrifugal separators for maximum recovery of neutral oil. Figure 2 shows a continuous process for alkali refining. Proportioned

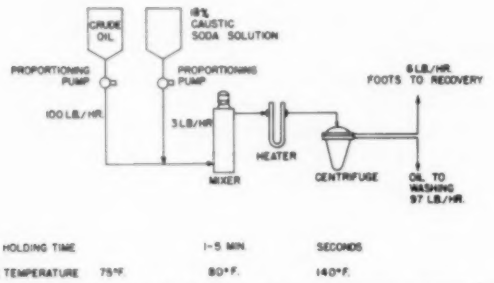


Figure 2. A schematic diagram of a continuous process for alkali refining.

quantities of crude oil and caustic soda solution at about room temperature are joined in flow, mixed vigorously for 1 to 5 minutes, heated to about 140° F., and then sent through a centrifuge for separation of "refined oil" from the sludge known commonly as "soapstock" or "foots." In some refining processes sodium carbonate solution is used as the alkaline agent, either alone or in combination with caustic soda solution. A two-stage refining procedure is not uncommon.

In the alkali refining of crude soya bean oil, the fatty acids and phospholipids are substantially removed. There is a minor loss in weight of other nonglyceride materials, but much of the total coloring matter is nevertheless removed. There is usually a "loss" of 1-2% neutral triglycerides emulsified in, and degraded to, "soapstock."

If water, instead of caustic soda solution, is used as the "refining" agent, the fatty acids would not be removed, but much of the phospholipid would. Crude lecithin can be produced by such a water-treating process, applied to crude soya bean oil.

The refined-oil effluent from the alkali refining process contains small quantities of residual moisture and of sodium soap. If not removed, these residues would cause deterioration during storage or in later processing—and increase bleaching and/or hydrogenation costs. These residual materials are removed in modern plants by a waterwashing process that is usually combined for economy with the bleaching process (Figure 3).

Hot water at about 10% of the oil weight is mixed intimately with the oil and then separated along with dissolved impurities through a centrifuge. Double-washing is sometimes employed. To the washed oil is now added about ½% of a bleaching clay, to adsorb color bodies. This oil-clay slurry is dried through a vacuum drier, and then filtered. The filtered oil is now virtually free of moisture and soap, and is very much lower in coloring matter.

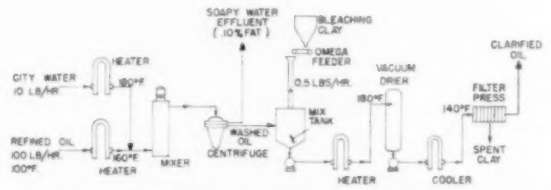


Figure 3. Schematic diagram of process for water washing and bleaching refined oil.

To produce a finished cooking oil, for example, the refined and bleached oil would be sent directly to the deodorizing process. In producing a shortening or a margarine, however, hydrogenation is usually required.

Hydrogenation. Introduced commercially into this country about 1910, hydrogenation has become the key process in the modern technology of fats and oils. It serves two important functions: first, it increases resistance to oxidative rancidity, which means prolonging the palatability of a food fat; and second, it increases the melting point, which means imparting to the fat desired plastic properties, at a chosen range of temperature.

Hydrogenation of an oil is simply the direct addition of hydrogen to a double bond in the fatty acid side chain. This addition of hydrogen reduces the iodine value and increases the melting point—that is, increases the "solid" glycerides in equilibrium at a crystallizing temperature. A change in iodine value also causes a proportional change in refractive index of oil.

The course of hydrogenation needs very close control. In an oil having a variety of fatty acids in the side chain—some of 3 double bonds and others of two, and still others of only one—it is important for the hydrogen to "select" one among 3 bonds, before it

selects one of two, before it selects the only remaining bond. The hydrogenation must be "selective" to prevent a rapid rise in solid glycerides before the oxygen-vulnerable multiple bonds are saturated. It is likewise desirable, for optimum balance between keeping quality and consistency, to minimize the development of high-melting unsaturated isomers. These isomers can, however, be useful in margarine, giving it working properties at room temperature but a melted condition in the mouth.

The hydrogenation reaction occurs in practice when an unsaturated oil, gaseous hydrogen, and an active catalyst, are brought together under the proper conditions. In the schematic flow diagram of a continuous hydrogenation process (Figure 4) an unsaturated oil is deaerated and dried, heated to hydrogenation temperature, and then combined with about

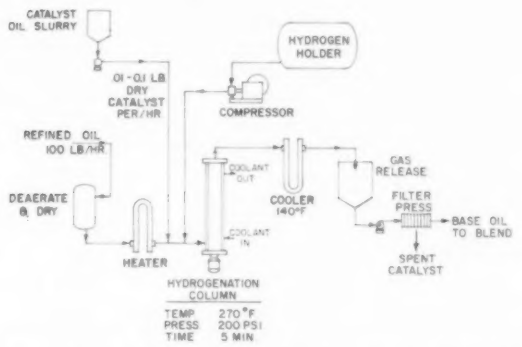


Figure 4. Schematic diagram of a continuous hydrogenation process.

.01–0.1%, oil weight basis, of an activated nickel catalyst, itself slurried in oil, and the combination delivered into an agitated reaction zone. The reaction is exothermic, requiring continuous heat removal to stabilize the temperature during the reaction. The stream of hardened oil from the reaction zone is cooled through a heat exchanger, freed of any unused gas, and filtered.

The *degree* of hydrogenation can be regulated by metering to the reaction zone the desired amount of hydrogen, or it can be regulated by *rate* of oil flow.

As hydrogenation proceeds, the change in refractive index of the oil provides a rapid measure of the hydrogenation that has taken place, although the more meaningful and more time-consuming measurements such as iodine value and the "Solids Content Index" are constantly determined.

Blending. Hydrogenation was used in the early days almost exclusively to produce a saturated high-melting "stearine." About 10–15% of this stearine was then blended with the original oil. When this melted blend was chilled over a cold roll, and gently agitated (or worked) during crystallization, a "compound"—as the early shortening was known—was produced. It had good plastic properties at use temperature.

Instead of fully hydrogenating only part of the oil, one can partially hydrogenate all of the oil to give what is known as an all-hydrogenated shortening. In this so-called all-hydrogenated shortening, however, about 80% by weight is actually liquid oil at room temperature. The remaining 20% forms the solid matrix that provides structure and plasticity. Not all of these solids are actually saturated.

The hydrogenated "base" without added stearine is very soft—i.e., lacks good plastic properties at room temperature—but when blended with a small percentage of stearine, it retains plasticity over a wider temperature range. The oil-stearine mixture possesses the widest plastic range, but has the disadvantage of oxidizing on the shelf, and in use, much faster than does the all-hydrogenated material. In current practice the degree of hydrogenation of the two fractions in a blend is varied to give the optimum balance of keeping quality and consistency, for the intended application.

Deodorization. As indicated earlier, refined and bleached oils, and also hydrogenated oils, contain minor quantities—probably less than 0.1%—of distasteful and odoriferous materials. Fortunately, these "impurities" are more volatile than the heavy triglyceride molecules and can be removed in a bona-fide distillation, known in the art as deodorization. The process is carried out under low pressure (usually 5–10 mm. Hg) and at high temperature (about 400° F.), with steam stripping. Since virtually complete removal of the distasteful impurities is required to produce a bland flavor, the process requires from one to three hours.

Figure 5 shows schematically the operation of a semi-continuous deodorizer. Batches of oil are transferred stepwise down the series of trays in the column. There are two heating trays at the top, three stripping trays in the center, and a cooling tray at the bottom. After deodorization, the oil is cooled to about 130° F., filtered through paper, and delivered to the plasticizing and filling operation.

In the best processes, the deodorized oil is brought to normal pressure by high-purity nitrogen, and protected by it through the filtering, plasticizing, and filling steps, to the point where the sealed container is opened by the consumer.

Plasticizing and filling. Mechanically driven, scraped-wall freezers turning out ice-cream at the refreshment stand are similar in principle to the freezers which, since their development in the early 1930's, have been used to crystallize food fats such as butter, margarine, and shortenings.

In the plasticizing step, the melted blend is delivered from a feed tank through a high-pressure pump to dissolve the nitrogen; it is then cooled within about thirty seconds to about 65° F., "picked" or worked gently for 1–4 minutes during which crystallization is virtually completed. It is then allowed to undergo a sudden pressure drop to *de-dissolve* and disperse the approximately 10% by volume of free nitrogen; and then filled directly into the container.

As soon as its flow is discontinued at the moment of fill, the fat "sets up," and is held in a storage

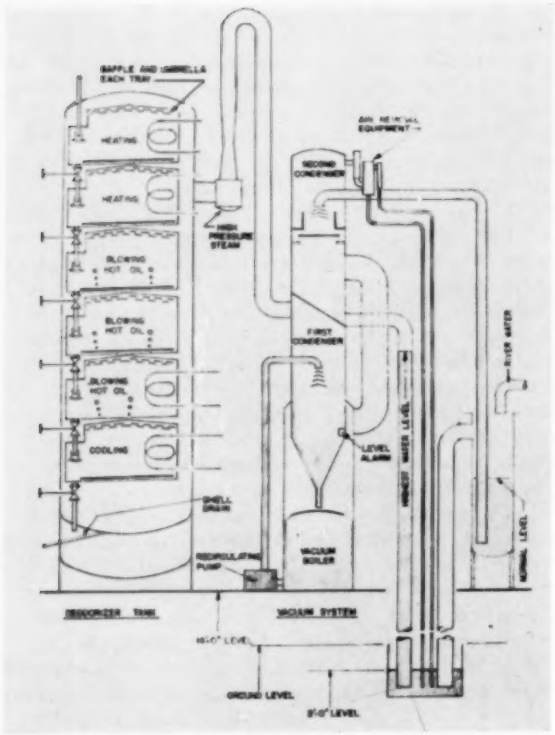


Figure 5. Schematic diagram of semi-continuous deodorizer.

room at controlled temperature for 24–48 hours to complete this set. These "finishing operations" seem simple enough, but must be closely controlled for uniformity of product. Differences in the temperature of the fat leaving the freezer cause a pronounced change in consistency. In practice, this temperature is controlled within $\pm 0.5°$ F., in the selected range.

If the shortening, immediately after filling, is allowed to take its chances on the weather—summer and winter—the consumer would get a product having widely different working properties. To prevent such variations, it is necessary to develop in the solid phase the proper crystal size and shape, their proper gross configuration, and the proper polymorphic form of the crystal.

SPECIALIZED PROCESSES

Polymorphism in fat crystals. A fully hydrogenated cottonseed or soya bean oil, a trisaturate, when crystallized from solution, may exist in one of 3 polymorphic forms, termed alpha, beta-prime or beta. The alpha phase exists temporarily but transforms quickly to one of the other two, the beta phase being the most stable. The fatty acid chains in the alpha phase crystallize perpendicular to the plane of the glycerine groups. There is, therefore, only one alpha phase; however, where the side chains crystallize at some angle other than 90°, several phases are possible. X-ray diffraction is used to get the "finger prints" of such phase structures. The stiffening effects of the solid trisaturates in a shortening depend upon the polymorphic phase of the solid crystals. Solids processed to be in the beta phase will produce a soft, flowable consistency in a finished shortening, whereas an equal amount of the same trisaturates processed to be in the beta-prime phase will produce a stiff consistency.

Suffice it to say that the food fat processor, by getting the right composition of the "solid" triglyceride, and regulating the conditions under which the crystals form, can produce either rigidity or fluidity in the liquid-solid system.

Interesterification. Mention has been made that the relative position of the component fatty acids on the glycerine radical determines many of the properties of natural fats. Thus the characteristic translucence that develops in the simplest lard shortening is thought to be due to the disaturated glyceride UPS (U = unsaturated, P = palmitic, S = stearic). If all the disaturated glycerides in lard (about 26%) were of this type, then an interesterification process that would give random distribution—that is, that would redistribute the component fatty acids according to pure chance—would in the process reduce this UPS component to a calculated 3.4% (natural lard contains about 63% unsaturated fatty acids, about 27% palmitic, and 10% stearic).

If the interesterification process is carried out at a temperature just below the melting point of the fat, trisaturates would begin to precipitate and would continue to precipitate as long as the liquid phase, seeking equilibrium, continued to produce them. It is to be observed that such directed interesterification forms tri-saturates *in situ*, whereas heretofore they have been generally formed separately by hydrogenation, for use in stiffening fat blends.

Figure 6 shows the per cent solids in equilibrium at varying temperatures for crude lard, "randomized" lard, and "directed" lard; and demonstrates the increased amount of high-melting (solid) glycerides developed in the lard by directed interesterification. The initially present but dispersed saturated acids have now been regrouped to form "trisaturates." There is no need here for an outside source of "stearine."

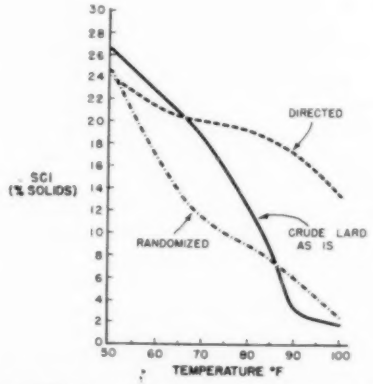


Figure 6. Solids content index vs. temperature: changes due to interesterification.

The directed lard would be produced as shown in Figure 7. The crude natural lard is heated to about 250° F. and vacuum dried; is cooled to about 90° F. and mixed with a sodium-potassium (NaK) alloy catalyst. Interesterification starts at once, and this active slurry is cooled and partially crystallized through freezers in 2 stages to about 75° F. It is held for perhaps an hour or so in crystallizers until the desired amount of precipitation has taken place. The catalyst then is inactivated by the addition of water, forming an alkali refining agent, and the mixture "refined" somewhat as described earlier.

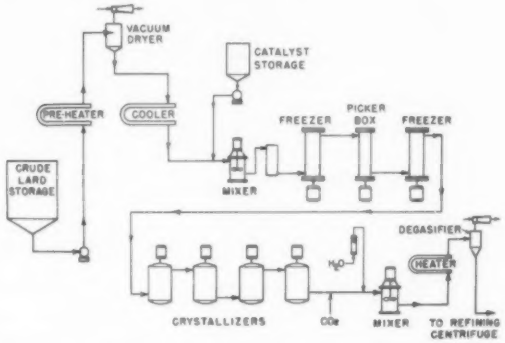


Figure 7. Schematic flow chart: directed interesterification.

Mono- and diglycerides. It was stated in discussing interesterification that under proper conditions the side chain fatty acids among triglycerides would exchange positions. In an analogous way, if a triglyceride and glycerine are brought together under the right conditions, the fatty acids of the triglyceride and the hydroxyls of the glycerine will exchange positions to a degree. The result is a mixture of glycerine, monoglyceride, diglyceride, and triglycerides. This in brief is the basis for making much of the monoglyceride used as an emulsifier in many foods.

Winterizing. A process called "winterizing" is used to remove high-melting glycerides. It is applied generally to cottonseed oil, corn oil, and to partially-hydrogenated soya bean oil, to remove those fractions of the oils that would crystallize at the temperature of home refrigerators. When used in mayonnaise, for example, such winterized oils would not disrupt the oil in water emulsion of mayonnaise at cold temperatures.

In the winterizing process, the oil is simply cooled to about 45° F., and the crystallized materials removed by filtration.

SUMMARY

In summary, the food fat processor can purify to a high degree the natural crude oils. He can change the character of the side chain fatty acids by hydrogenation, and change their relative positions in the triglyceride randomly or controllably by interesterification. He can create solids *in situ*, add them or remove them, and have them assume a stiffening or non-stiffening character. With such flexibility he is providing the public with a variety of palatable and nutritious foods; and if the need arises for fats with special nutritional properties, he has the means to produce them.

The Visible Fats in Our Diet[a]

K. F. Mattil
Swift & Co., Chicago

(Manuscript received June 19, 1958)

THERE HAS BEEN considerable interest in the past several years in the trends in consumption of food fats in the United States. This has been the subject of discussion in a multitude of scientific meetings and of many papers in technical journals, and has been widely discussed in the lay press. In most instances, the basic data used have been taken from U. S. Government publications, reporting information collected over the past 50 years by the Department of Agriculture and the Bureau of Census. This is also true in this paper.[b] However, rather than simply discussing the data as lifeless statistics, we will try to point out some of the factors that have influenced the trends. Especially we will try to show the part played by food technologists, and perhaps indicate how we may exert an influence on the future.

A strongly implanted preference. To find the beginnings of the modern trends, one must go back at least to the end of the Civil War. Partly because of their northern and western European backgrounds, the people of our country had a strongly implanted preference for butter and lard as table and culinary fats. These two represented the bulk of the food fats used at that time. The beginning of the shortening industry was found in the adulteration of lard with less costly fats. The rise of the margarine industry in the 70's and 80's stimulated the adulteration of lard; that is, leaf lard was segregated for margarine so that the remaining lard was softer and needed stiffening; and oleo stearine, a by-product from the manufacture of oleo oil used in margarine, made an unusually good stiffener for lard.

Also in the 70's and 80's we saw a rapid expansion in the production of edible oil expressed from cottonseed. Until shortly before the Civil War, cottonseed oil was not produced commercially. In 1867, there were only four cottonseed oil mills in this country; by 1880, there were 45, and in 1890, there were 119. In Figure 1 is shown the growth in production of cottonseed oil from 1875 to 1905. The large lard refiners quickly recognized the possibility of extending their production of lard with this relatively inexpensive oil. Unfortunately, however, the natural color and odor of cottonseed oil limited its use. Probably largely for that reason, one of the large lard refiners, the N. K. Fairbanks Company, employed a chemist in 1879. He rapidly built up an effective research and development staff that is reported to have kept this company ahead of its competitors for the next 20 years. Naturally, the competitors followed quickly in setting up research and development teams of their own, some of whom were proselyted from Fairbanks.

Decolorizing, deodorizing stimulate use. In interpreting the rapid growth in production and use of cottonseed oil, it is possible to suggest two different views: (1) the increase in production caused the refiners to find ways of using the oil, or (2) the fact that the refiners found means for increasing its use stimulated the oil mills to increase production. The actual cause and effect pattern probably lay in between these two extremes. From the point of view of the refiners, the lower cost of the cottonseed oil was certainly a strong incentive to find ways of using it. While necessity may be the mother of invention, in many cases a penny differential in prices has been the father. Consequently, the Fairbanks' chemists almost immediately developed a method for decolorizing cottonseed oil with adsorptive earths. In the next decade, they worked on better methods of deodorization, and by 1891, had effected substantial improvement by blowing high pressure steam through the oil at 340° F. About 1900, vacuum deodorization was developed by a former Fairbanks chemist who was by then in the employ of a competitor.

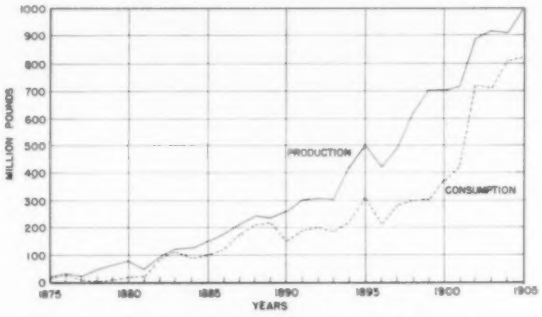


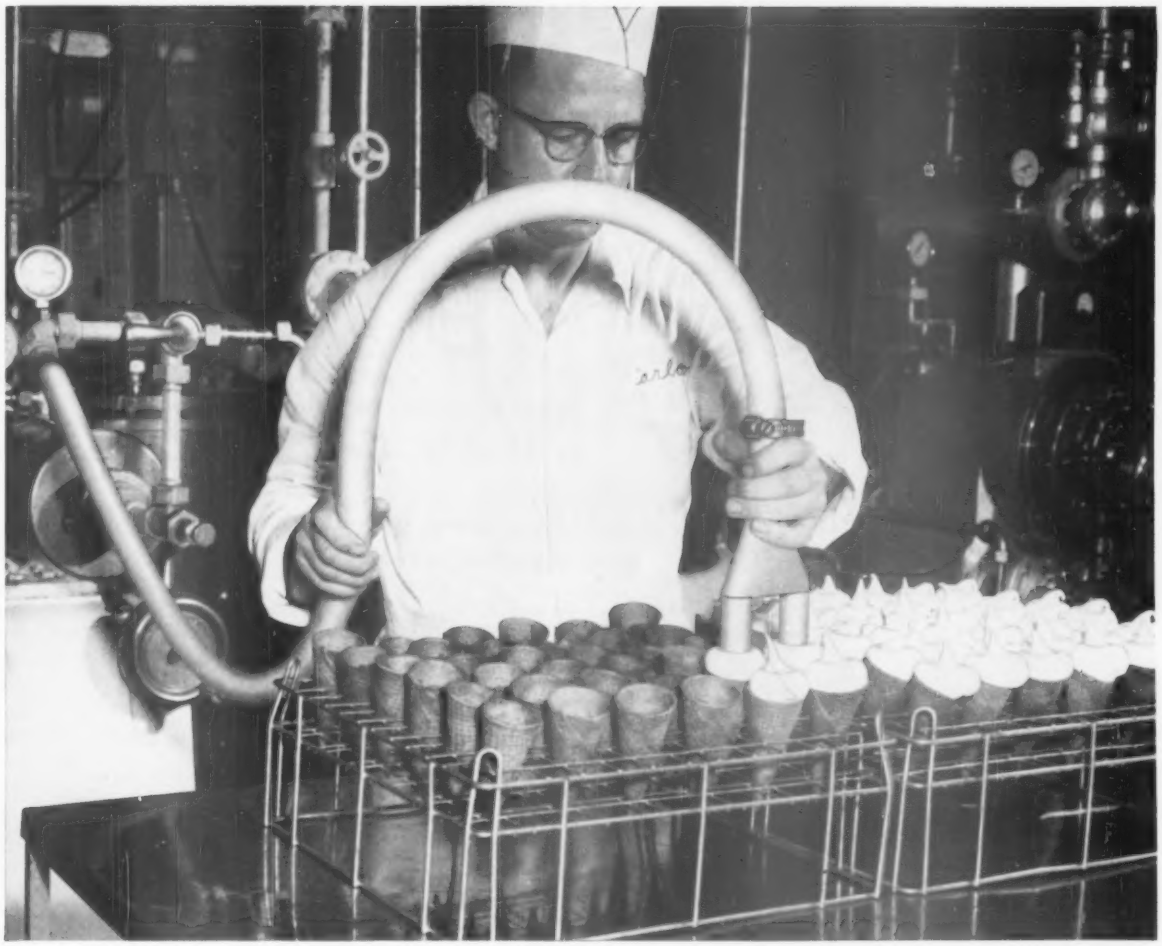
Figure 1. Cottonseed oil production and domestic consumption, 1875–1905.

"COMPOUND"

It is believed that by 1887, a substantial portion of the entire cottonseed oil output was being used in lard or in lard substitutes. By that time, the term "compound lard" began to appear. A typical formula for this type of product, obviously not lard at all, was a blend of about 80 parts cottonseed oil and 20 parts oleo stearine. This was the beginning of the shortening industry—and by shortening, we refer to plastic fat products other than lard. There are conflicting estimates on the amount of "compound" produced, but by 1890 it is estimated at about 150–200 million pounds, or about one-fourth the total domestic consumption of lard. This is at the rate of 3 lbs. per capita with lard at that time estimated at 12 lbs. per capita.

[a] Presented at the Symposium on Fats in Food, Eighteenth Annual Meeting of the Institute of Food Technologists, Chicago, May 29, 1958.

[b] *The American Vegetable Shortening Industry* by Weber and Alsberg *(3)* supplied additional data to that given in USDA publications *(1, 2)* and was also the source of much of the historical information.



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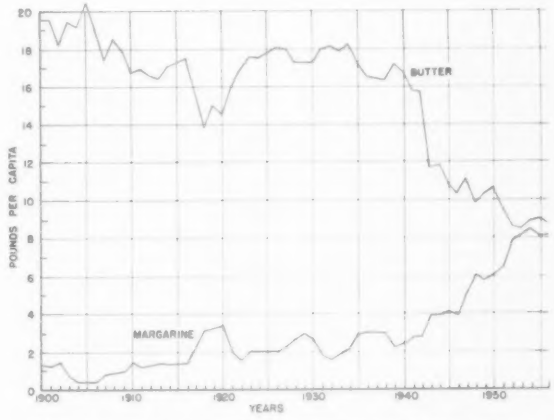

Figure 2. U. S. per capita consumption of butter and margarine, 1900–1956.

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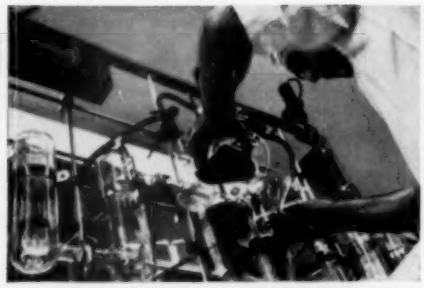

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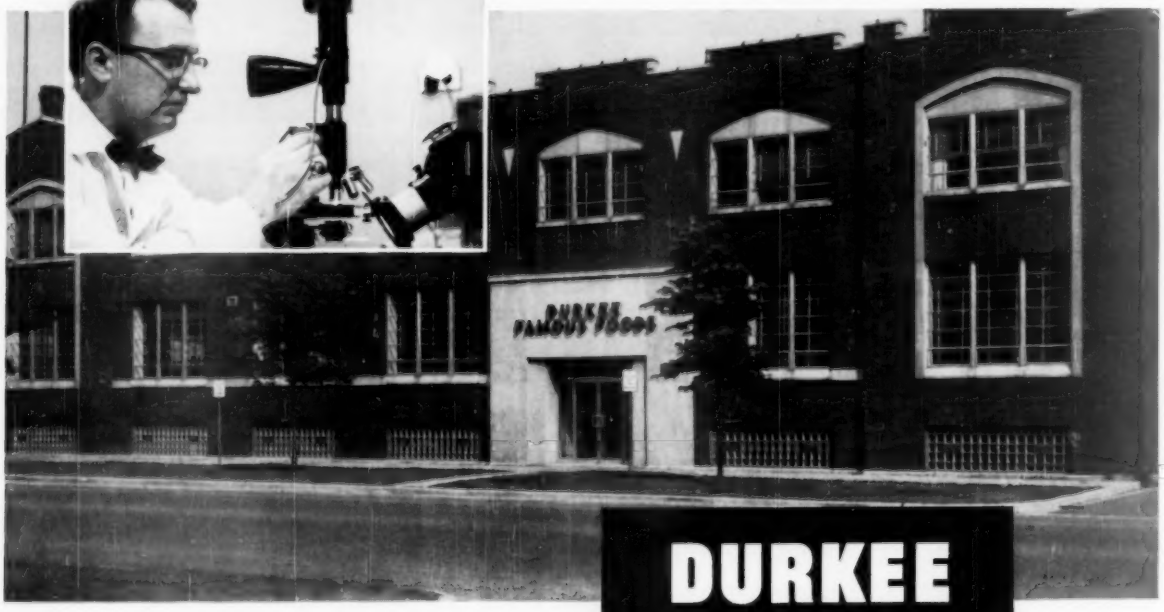

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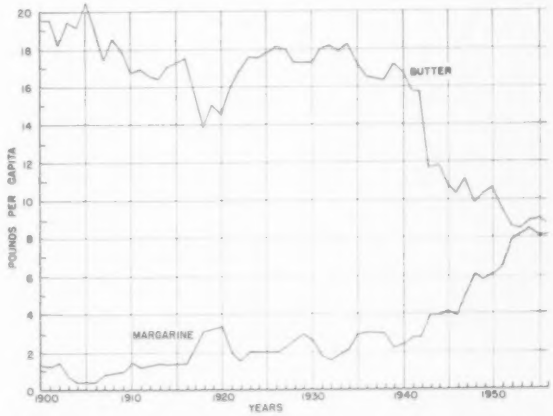

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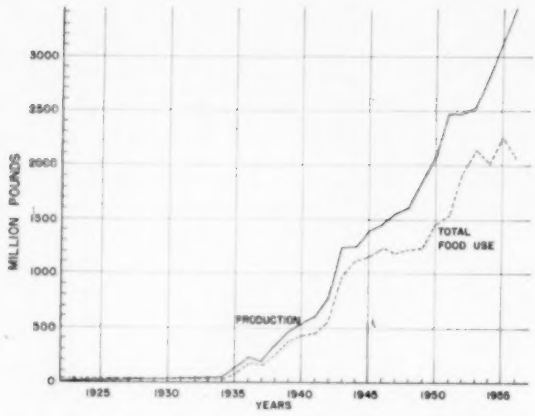

Figure 3. U. S. production and total food use of soybean oil.

necessary to sell the oil at a substantial price discount. And the food manufacturers urged their technologists to find means for using this low priced oil. The big disadvantage that had to be overcome was the flavor instability of soybean oil and products made from it. So once again, the race between production and technology began. The results are quite apparent from Figure 3. Where 20 years ago very little soybean oil was being used in food products, today it is *the* major component of margarine and shortening, and much is used as the liquid oil. Most of that used in margarine and shortening is hydrogenated as one of the important factors in controlling flavor stability.

The net effect of this tremendous growth in the consumption of vegetable oils in the past 40 years is shown in Figure 4. We pointed out previously that the consumption of shortening grew from nothing in 1880 to about 10 pounds per capita by the end of World War I. Since that time there has been little change in its per capita consumption. Its composition has changed in that hydrogenated soybean oil and more recently lard have displaced much of the cottonseed oil and hydrogenated cottonseed used formerly. The consumption of lard has remained fairly constant and is no different now than estimates going back as far as 1880. Not only has margarine increased in consumption, but here, too, hydrogenated cottonseed oil has been replaced to a considerable extent by hydrogenated soybean oil. Much of the displaced cottonseed oil and some of the soybean oil account in large part for the increase in the category designated "other." This comprises chiefly salad and cooking oils, and oils used in mayonnaise, salad dressings, etc. Practically all the oils in this category are used unhydrogenated. It is interesting to note that this use of unhydrogenated vegetable oils has about tripled in the past 40 years. It has gone from essentially nothing in 1880 to about 10 pounds per capita today.

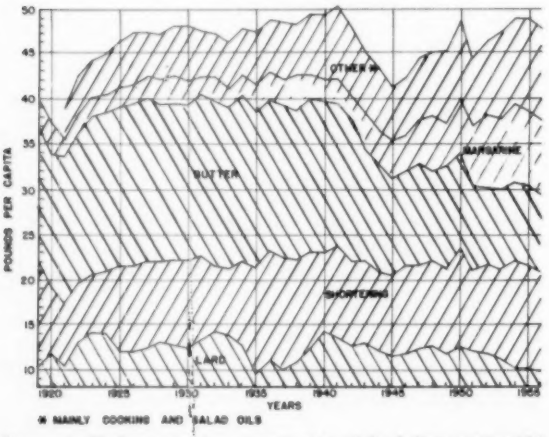

Figure 4. U. S. per capita consumption of food fats, 1920–1956.

OTHER OILS

What about the other oils? One can best judge their position by seeing a comparison of production data shown graphically in Figure 5. As a source of supply of raw materials to the food processor, only soybean oil, cottonseed oil and lard are produced in sufficient quantities at the present time. An increase in the production of either peanut oil or corn oil does not immediately appear to be economically feasible. Most of these two oils is now being used in salad and cooking oils. The production of peanut oil is limited by its cost, and corn oil by the fact that it is a by-product and represents such a small proportion of the raw corn. Its situation in this respect is like that of cottonseed oil, whose production has tapered off because the demand for cotton has been seriously affected by the development of synthetic fibers. Because of the inherent nature of the beef industry, only a small proportion of the total supply of beef fats can be used in food. Our production of inedible tallow is nearly ten times the amount used for edible purposes.

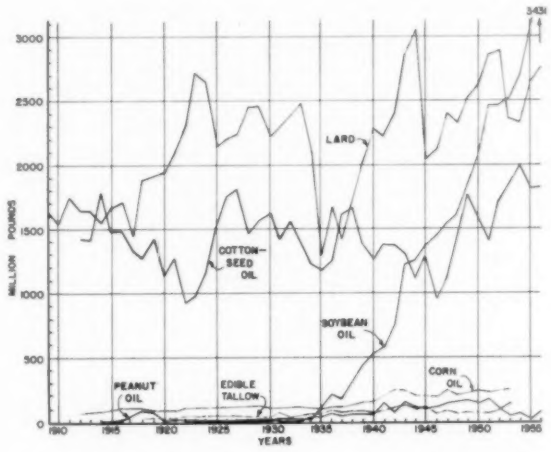

Figure 5. U. S. production of various food fats, 1910–1956.

THE MAJOR CHANGES IN CONSUMPTION PATTERNS

It has been popular in the past few years to relate trends in fat consumption to various public health matters, especially atherosclerosis. Many of the correlations that have been made could be misleading in that they were based on situations that existed at two isolated periods of time without taking cognizance of the pattern of events in between. Apparently they presumed a gradual transition from one set of conditions to the other. Obviously, one's conclusions would be quite dissimilar if one compared today's consumption patterns with 1880, 1900 or 1920. What then have been the major changes?

1. One must first point out the tremendous growth in the vegetable oil industry. In 1880, our diet contained very little vegetable fat other than those consumed as invisible fats in their natural form. Today, vegetable oils represent more than half of our supply of visible fats.
2. It appears that the greatest increase in per capita consumption of visible fats, estimated at about 9 pounds, occurred between 1880 and 1910. This was predominantly accounted for by the growth in the cottonseed oil industry.
3. There has been a smaller increase in per capita consumption of visible fats since 1910.
4. In the period 1911–1920, there was a major conversion to hydrogenation, especially of vegetable oils, in the manufacture of shortening.
5. In the past 20 years, there has been a substantial substitution of margarine for butter.
6. This same 20 years saw the remarkable growth of the soybean oil industry.
7. Over the past 50 years, there has been a steadily increasing consumption of unhydrogenated vegetable oils.

There have been a number of attempts in the past several years to calculate trends in consumption of specific fatty acids, particularly saturated acids and linoleic acids. This is an undertaking fraught with many pitfalls, because of the number of assumptions that must be made. First of all, what formulas must be assumed for the margarines and shortenings that have been made at various periods of time? Even today's products cannot be assigned a single value, as they will vary quite widely from one manufacturer or formula to another. Then what analyses are to be assumed for the various products? It is no wonder that different people, using different assumptions, have arrived at different conclusions. To add to the confusion, we have calculated (using our own set of assumptions) the proportion of linoleic acid and saturated acids in the visible fats consumed since 1880 as follows:

	Linoleic acid	Saturated acids
1880	6%	49%
1910	17%	43%
1920	13%	45%
1956	17%	33%

THE NEXT BIG RACE BETWEEN PRODUCTION AND TECHNOLOGY

Where do we go from here? Obviously, the future depends heavily upon supply and demand. At the moment, it looks like our supply of cottonseed oil may decrease, and soybean oil continue to increase. Many medical and nutrition research workers are urging an increase in the proportion of linoleic acid we consume. There are suggestions that we consume more corn oil, apparently without recognition of the limitations on the potential production of this oil. An even scarcer oil that is much talked about is safflower oil, noted principally for its high linoleic acid content. At the present time this oil is truly a "drop in the bucket" and its production on a large scale will have to be preceded by a major agronomic research program. Other than cottonseed oil, our big potential supply of linoleic acid now is soybean oil. But before we can take advantage of this source, provided there is a real public health need, our scientists must learn how to use unhydrogenated soybean oil satisfactorily in margarine and shortenings. This is our big challenge today, and may turn out to be the next big race between production and technology.

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Experimental Studies on Dietary Fats, Cholesterol, and Atherosclerosis[a]

Jeremiah Stamler, M.D.[b]

Chicago Board of Health, Chicago, Illinois

(Manuscript received July 19, 1958)

IN APPROACHING A DISEASE of unknown or obscure etiology—and it is appropriate from the start to say that the etiology of atherosclerosis is not yet fully understood—medical science has three basic methodological techniques. They are, first, the clinical-pathological approach, i.e. the study of the disease in living individuals and at postmortem; second the animal-experimental method, i.e. the reproduction and the study of the disease in experimental animals; and, third, the epidemiological approach, i.e. the study of patterns of occurrence of the disease in populations. Dr. Stare, in his presentation,[c] will deal with results and problems of research utilizing methodologies 1 and 3. My remarks here today will focus on experimental research on atherosclerosis.

DEFINITIONS—ATHEROSCLEROSIS AND ARTERIOSCLEROSIS

In order to be certain that full clarity prevails on the subject under discussion, it is in order to deal briefly with definitions. Many knowledgeable individuals, including physicians, are not entirely clear on the distinction between the terms arteriosclerosis and atherosclerosis. Pathology made a very clear distinction between these terms many years ago *(19, 22)*.[d] Arteriosclerosis was designated as a generic term encompassing all the vascular scleroses, or pathologic processes producing thickening and hardening of the vessels. Several different processes—almost certainly with different etiologies — produce abnormalities in the vessel wall of the sclerotic variety. In order to point up its generic nature, it would perhaps be better to use the term, *the arteriosclerоses.*

Atherosclerosis is a specific disease process, one among the arteriosclerоses. In terms of production of human morbidity and mortality, it is by far the most important entity among the arteriosclerоses. Atherosclerosis, for example, is the underlying pathologic lesion in at least 90% of cases of myocardial infarction (heart attack). Among middle-aged Americans (not to speak of the elderly), particularly among middle-aged American males, atherosclerosis of the coronary arteries (coronary heart disease) is the chief cause of death (Figure 1) *(33)*[d]. It is responsible for one-third of all deaths in white males aged 45–54. It is, therefore, the number one public health problem in our country today.

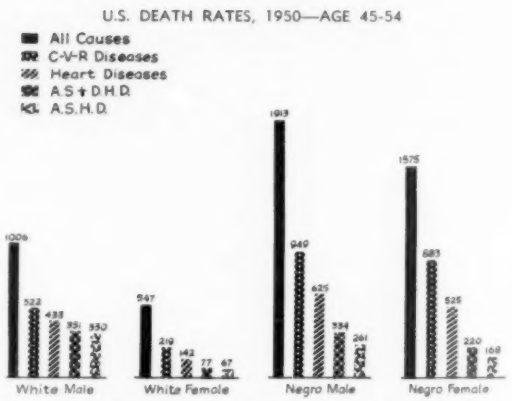

Figure 1. The death rates are per 100,000 population, A.S. + D.H.D. is arteriosclerotic plus degenerative heart disease (categories 420 + 422 in the 7th revision of the International Statistical Classification of Diseases and Causes of Death). A.S.H.D. is arteriosclerotic heart disease (category 420). Note the high death rates for arteriosclerotic heart disease. Note also the sex difference in arteriosclerotic heart disease mortality rates.

PATHOLOGIC DESCRIPTION OF ATHEROSCLEROSIS

Atherosclerosis is primarily a lesion of the inner lining (intima) of the wall of large and small arteries. The morphologic hallmark of this lesion—recognized in the early days of scientific cellular pathology over 100 years ago—is its content of fatty materials, neutral fats, phospholipids, and particularly cholesterol. These are very often distinguishable grossly, and almost invariably microscopically.

Considerable evidence is available indicating that deposition of fatty materials is the initial process in atherogenesis. As the lesion develops, these lipids accumulate both intracellularly and extracellularly, in globules and amorphous pools. Concomitantly necrotic and proliferative processes supervene, resulting in fibrosis, scarification and calcification. The term *atherosclerosis*—derived from the Greek *athere*, meaning mush, and *skleros*, meaning hard—therefore characterizes the lesion well.

This lesion is a menace to health for several reasons. Involving the inner lining of the vessel wall, it tends to impinge upon the lumen, narrow the diameter of the vessel and in that way cut down the flow of blood. In addition, the lesion as it evolves may become a nidus for clot formation (thrombosis) with

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[a] Presented at the Symposium on Fats in Food, Eighteenth Annual Meeting of the Institute of Food Technologists, Chicago, May 29, 1958.

[b] Director, Heart Disease Control Program, Chicago Board of Health; Associate, Department of Medicine, Northwestern University Medical School.

[c] See page 33, this issue.

[d] More extensive bibliographies have been included in recent reviews *(19, 20, 33)*.

closure of the vessel and death (infarction) of an area of the organ (heart, brain, kidney, extremity, etc.). Further, the lesion may become capillarized (normally the inner layer of vessel wall is not capillarized, but gets its nutrients from the stream of blood flowing through it). These capillaries in atherosclerotic plaques may rupture, producing hemorrhage in the lesion, with consequent swelling (as a blood blister swells the skin). This process also leads to narrowing or closure of the vascular channel, with infarction of tissue. Clinical manifestations of atherosclerotic disease—e.g. a heart attack or stroke—are often a consequence of one or another of the foregoing "complications" of the basic pathologic process.

EARLY ATTEMPTS TO PRODUCE ATHEROSCLEROSIS IN ANIMALS

With this brief introduction to the pathology of the disease, let us proceed to the experimental aspects. Once this lesion was clearly identified by the early cellular pathologists, attempts began to reproduce it in laboratory animals. Throughout the second half of the nineteenth century, up until 1908, considerable experimental work was done, involving a variety of approaches, depending upon the hypotheses of the various investigators. For example, efforts were made to induce atherosclerosis with toxins, bacteria, pressor and depressor substances, hormones, mechanical injury to vessels, etc., etc. *(9, 17)*. Not unexpectedly, some of these procedures did produce pathological changes in arteries, but never atherosclerosis. The lesions resembled virtually every type of arteriosclerosis seen in man, except atherosclerosis.

This historic experience is very important, because it constitutes substantial evidence, of a negative type, ruling out several processes as decisive or primary or sole factors in the causation of this disease. (This does not mean that they play no role in its pathogenesis or etiology. As we shall see, subsequent experimental work has yielded substantial evidence indicating an adjuvant role for several of these agents in the multifactorial causation of atherosclerosis.)

PRODUCTION OF ATHEROSCLEROSIS IN RABBITS BY DIETARY MEANS

Atherosclerosis was first successfully produced in animals in the period 1908–10 by a group of Russian scientists led by Anitschkow *(3)*. In the course of a study on the relationship of diet to kidney function and high blood pressure, these workers fed whole animal tissues to rabbits. After a considerable period of time on this regimen, the animals were observed at postmortem to have developed atherosclerosis.

In subsequent experiments, Anitschkow vigorously followed up this lead. He recognized that the whole animal tissues fed to the rabbits contained both animal fats and proteins. He also noted that these animals were markedly hyperlipemic, and that the atherosclerotic lesions were laden with lipids. He therefore set out to determine whether the lipids (neutral fats and cholesterol) or the proteins in the rabbits' diets were the atherogenic factors. He was soon able to demonstrate that hypercholesterolemic hyperlipemia and atherosclerosis could be produced by feeding rabbits pure cholesterol and fat. This achievement stimulated a tremendous amount of research during the second and third decades of this century, principally in Russia, Germany, and United States *(3, 9, 17)*.

CRITIQUE OF THE EARLY RABBIT EXPERIMENTS

By the 1930's a considerable disillusionment with this trend of experimentation had developed among some investigators *(14)*. It is important to know the reasons for this disillusionment. First of all, it was noted that the atherosclerotic lesion—readily induced in the herbivorous rabbit by cholesterol-fat feeding—was induced only inconsistently or not at all in most other species at that time. Completely negative results had been obtained in dog, monkey, rat. These failures led many workers to stress the fact that the rabbit is a herbivore, and as a herbivore does not normally ingest cholesterol (a sterol present exclusively in animal tissues). It was argued that—since man is an omnivorous species[e]—the results of cholesterol feeding experiments in rabbits are in no wise analogous to events occurring in man.

It was further noted in the critical discussion of the 1930's that rabbits on their usual diets do not spontaneously develop atherosclerotic lesions. It was also pointed out that cholesterol-fat-fed rabbits exhibit marked hypercholesterolemia and extensive deposition of cholesterol and fat in organs. Except for rare cases of severe essential familial xanthomatosis, these phenomena are not observed in human beings with atherosclerotic disease.

For all the foregoing reasons, serious questions were raised concerning the meaning and significance of this animal research for the problem of atherosclerosis in man. This set of unresolved scientific problems, plus the economic stringencies of the 1930's, led to a stagnation of research in this field.

PRODUCTION OF ATHEROSCLEROSIS IN OTHER SPECIES BY DIETARY MEANS

During the last 10–15 years, however, a tremendous resurgence of animal experimentation has occurred, leading to a solution of most of the problems noted in the foregoing critique. It was these problems that led Dr. Deborah V. Dauber (deceased) and Dr. Louis N. Katz in the Cardiovascular Department, Michael Reese Hospital, to undertake research in a species other than the rabbit. During the early 1940's, they deliberately elected to work with the chick, mainly because the chick is an omnivore that spontaneously

[e] Incidentally one can make a case for the thesis that man evolved from an herbivorous line. But it is certainly true that for tens and even hundreds of thousands of years man has been omnivorous. Recent research has in any case rendered this argument irrelevant—see below.

develops arteriosclerosis *(11, 12, 13, 18)*. (Originally this lesion was thought to be atherosclerosis, but subsequent work showed it to be an intimal fibrosis, i.e. a non-atherosclerotic arteriosclerosis.) It was soon found—in verification of previous fragmentary work by Japanese investigators—that chicks fed fat and cholesterol develop hypercholesterolemic hyperlipemia, visceral cholesterosis and gross atherosclerosis of the aorta, the coronary and other arteries.

I became associated with this research effort in 1948, after the untimely death of Dr. Dauber. One of the first problems to be tackled was the matter of massive hypercholesterolemia and organ cholesterosis. It was shown that cockerels fed smaller quantities of fat and cholesterol over longer periods of time, e.g. mash supplemented with 5% fat plus ¼% cholesterol —amounts quite similar to those in prevailing American diets — develop moderate hypercholesterolemia, with little or no organ cholesterosis. After about 9 months on this diet, gross atherosclerosis supervened (Figure 2) *(36)*. Incidentally, Anitschkow had in the 1920's reported similar findings in rabbits *(3)*. Thus one important criticism of the animal-experimental work was met.

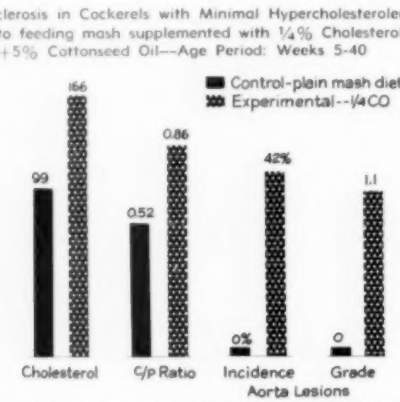

Figure 2. C/P ratio is the ratio of serum total cholesterol to total phopholipids. ¼ CO is mash supplemented with ¼% cholesterol (C) + 5% cottonseed oil (O). These symbols for dietary supplements are used in all subsequent figures. The incidence of lesions is the percent of birds with gross aorta lesions at the end of the experiment. The grade is the mean grade of lesions in birds with lesions, on an arbitrary scale 0–4.

During the last several years, atherosclerosis has been successfully induced in other major laboratory species, omnivorous, carnivorous, herbivorous—e.g. rat, dog, monkey, guinea pig, pig, hamster, duck, goose *(19, 25, 34, 42, 46, 47)*—thus disposing of a second major criticism of the earlier experimental work. It is of decisive theoretical importance to recognize the common feature which characterizes all recent experiments on different species. Invariably—with a few "exceptions," which are not really exceptions at all, as we shall soon see—in all species studied the *sine qua non* for inducing atherosclerotic lesions proved to be *a dietary alteration involving increased intake of fat and cholesterol, resulting in a sustained hypercholesterolemic hyperlipemia.* (It should be noted that the type of fat apparently is not a critical factor in experimental animals, in seeming contradiction to recent findings in man. We shall return to this problem later.)

In the dog, for example, hypercholesterolemia and atherosclerosis were induced by feeding a high-fat, high-cholesterol diet and rendering the animal hypothyroid. In the rat and the monkey, hypercholesterolemia and atherosclerosis were produced by feeding a diet high in fat and cholesterol and deficient in the sulfur-containing amino acid, methionine. (This finding posed the important problem of possible interrelationships among the major nutrients in the process of atherogenesis—a problem to which we shall return later.)

Having formulated the key generalization that a high intake of fat and cholesterol, leading to sustained hypercholesterolemia, is the prerequisite for atherogenesis, we may now examine the aforementioned exceptions and attempt to interpret them. First, it has been reported that geese made obese by carbohydrate force-feeding (a la the procedure for commercial production of pâté de foie gras, or fatty liver, in plain laboratory English) develop moderate hypercholesterolemia and, after many months, moderate atherosclerosis *(47)*. When cholesterol is incoporated in this dietary regimen, the hypercholesterolemia and atherosclerosis develop more rapidly and more severely. Second, rabbits fed a diet of peanuts, containing no cholesterol, but sizable amounts of plant sterols and fats, develop moderate hypercholesterolemia (hypersitosterolemia—?—J. S.) and after many months, slight atherosclerosis—a much milder metabolic and pathologic change than occurs when cholesterol is incorporated in a similar ration for rabbits *(42)*. Third, ground squirrels—experiencing cycles of feeding, weight gain, fat accumulation and fat mobilization in relation to hibernation—develop slight hypercholesterolemia and slight atherosclerosis over the course of several months on non-cholesterol-containing diets *(6)*. Finally, rabbits fed highly saturated hydrogenated coconut oil for several months develop a considerable hypercholesterolemia and lesions without incorporation of cholesterol in the diet *(23)*.

These experiments indicate that high fat and/or fattening regimens, even though devoid of cholesterol, may over a relatively long period of time induce moderate hypercholesterolemia and atherosclerosis, at least in the more susceptible species. They further demonstrate that incorporation of cholesterol in the respective diets markedly accelerates their hypercholesterolemic and atherogenic effects. Finally, they point to the decisive conclusion that combining a high intake of calories, fats, saturated fats, cholesterol, refined carbohydrates is particularly pernicious in its proclivity for producing hyperlipemia, hypercholesterolemia and atherosclerosis. They serve to emphasize the validity of the key generalization to be derived from the extensive experimental work, i.e. that *there is a significant interrelationship among habitual diet, cholesterolemia and atherogenesis.*

RECENT EXPERIMENTATION

The successful production of atherosclerosis in a host of animal species stimulated a fresh wave of intensive research on the parameters of the phenomenon. Two main lines of work have generally been pursued: the study of the interplay (1) among various nutrients (e.g. vitamins, minerals, amino acids, individual lipids), and (2) between exogenous (dietary) and endogenous (e.g. hormonal) factors. This latter area of animal experimentation is not the subject of the present report, and will therefore be merely touched on here (cf. refs. *16, 19, 20, 33, 34, 37*).

THE EFFECTS OF DIFFERENT FATS

In the area of dietary interrelationships, recent studies on the effects of unsaturated vegetable oils on cholesterolemia in man *(1, 2, 5, 7, 21, 24)* have led to exploration of this problem in experimental animals. Before consideration of the newer findings, it is worth re-emphasizing that for decades experimental atherosclerosis was routinely produced—originally in rabbits and latterly in chicks and other animals—by feeding diets containing cholesterol and unsaturated vegetable oils *(3, 9, 17, 19)*. In apparent contradiction to the limited findings of some supplementation studies in man,[f] the incorporation of large amounts of unsaturated vegetable oils in the high-cholesterol diets of experimental animals did not inhibit hypercholesterolemia or atherogenesis. In fact, it is an old observation in rabbits and chicks that ingestion of mash supplemented with cholesterol plus vegetable oil resulted in more marked hypercholesterolemia than feeding mash plus cholesterol alone. Further, as already noted, rations high in unsaturated vegetable fats (e.g. from peanuts) may induce hypercholesterolemia and atherogenesis in rabbits and squirrels in the complete absence of dietary cholesterol *(42)*. Again, these are results in apparent contradiction to those in men.

Recent experiments further showed that feeding chicks mashes supplemented with various lipids at the 5–10% level—e.g. relatively saturated lard, hydrogenated vegetable fat or coconut oil vs. unsaturated oils (linseed, cottonseed, corn oil)—yielded little or no difference in hypercholesterolemia and atherogenesis (Figures 3–6) *(38)*.

On the other hand, in a similar experiment comparing an oleic acid concentrate vs. cottonseed oil in cholesterol-fed cockerels, atherogenesis was found to be less marked (although hypercholesterolemia was unaffected) in the birds ingesting large amounts of oleic acid. Further, as already noted, other workers observed that long-term ingestion of highly saturated coconut oil (without cholesterol) induced hypercholesterolemia and atherosclerosis in rabbits, whereas eating a ration high in unsaturated safflower oil had no such effects. A few other experiments have been reported showing differences in animals with different fats and oils.[g]

In calling attention to the apparently divergent results of experiments with unsaturated vegetable oils in man vs. chick and rabbit, it is essential to note

[f] For a review of these human studies, cf. refs. *(20, 33, 34, 35)*.

[g] For a review of the recent voluminous literature in this area, see references *(20)* and *(34)*; also see the 1957 and 1958 Federation Proceedings *(27, 28)* and the 1957 Proceedings of the American Society for the Study of Arteriosclerosis *(29)*.

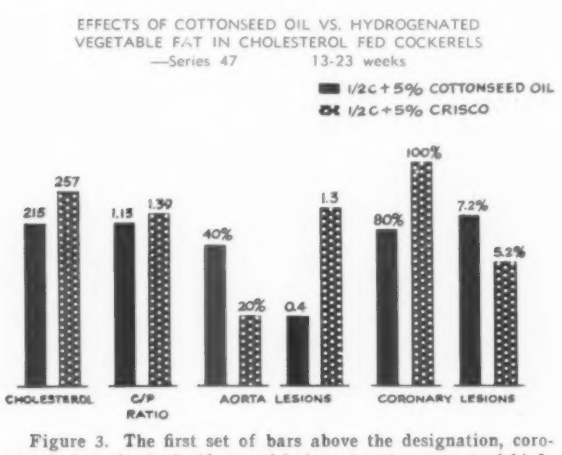

Figure 3. The first set of bars above the designation, coronary lesions, is the incidence of lesions, i.e. the percent of birds with microscopic lesions. The second set of bars (7.2%, 5.2%) is an index of incidence of severity of microscopic coronary atherosclerosis. It is the percent of vessels showing coronary atherosclerotic plaques, among all vessels visualized in two standard sections of the heart studied microscopically.

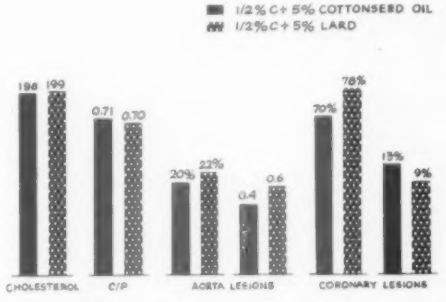

Figure 4. Effects of saturated animal fat vs. unsaturated vegetable fat in cholesterol-fed cockerels, S-37—12–17 weeks.

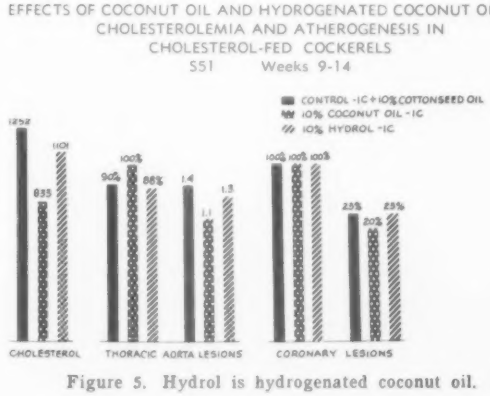

Figure 5. Hydrol is hydrogenated coconut oil.

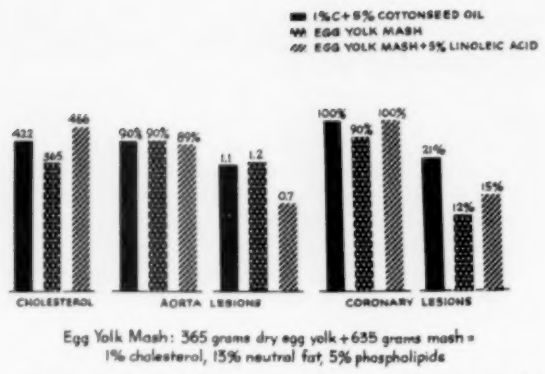

Figure 6. Effects of egg yolk and egg yolk plus linoleic acid, S-46—8–15 weeks.

the differences in experimental design. Except for a few of the human studies, the subjects investigated were persons on American-type high-calorie, high-fat, high-saturated-fat, high-cholesterol diets. Concomitantly, they manifested moderate or marked hypercholesterolemia. Most of the positive studies in such people were of the complete or partial substitution type, involving withdrawal of saturated fat and cholesterol, and incorporation of unsaturated vegetable oil. These investigations were patently not analogous in design to the aforementioned animal experiments. The latter involved the addition of cholesterol and unsaturated vegetable oil to the low-fat, low-cholesterol ration of rabbits and chicks exhibiting low-normal serum cholesterol levels.

It would appear that further animal experiments are essential, utilizing a design similar to the human studies, and vice versa. Until these are accomplished, it would be premature to attribute the seemingly disparate findings in animals and man to "species differences." In any case, should species differences actually be demonstrated, their mechanism becomes an important problem *per se*.

In connection with this discussion on the effects of different fats and oils, a comment is in order on the current hypothesis that atherosclerotic disease may be a resultant of dietary deficiency of essential fatty acids (EFA) *(32)*. The animal-experimental evidence certainly does not support this hypothesis. Obviously, from the foregoing experiments, atherosclerosis can be readily produced in chicks and rabbits by cholesterol feeding—even in the presence of large amounts of high-EFA unsaturated vegetable oils. In fact, their presence in the diet is often associated with enhanced hypercholesterolemia and atherogenesis. Moreover, it has been shown that cholesterol-fed cockerels have normal levels of polyenoic fatty acids in their sera and tissues *(10)*. Thus, the atherogenic process is not associated with mensurable signs of any EFA deficiency. All these experimental facts cast serious doubt upon the speculation that atherogenesis is a resultant of EFA deficiency.

Here it is important to recall the experimental conditions required for the production of true EFA deficiency in animals. As the original work by Burr and Burr over two decades ago demonstrated, signs of EFA deficiency can be elicited only by accomplishing virtually complete removal of all fat from the diet *(8)*. The incorporation of only slight amounts of any natural fat (animal or vegetable) in the experimental ration rendered impossible the production of signs of EFA deficiency.

Recently it was shown that EFA deficiency is more readily and rapidly produced when a diet rigidly devoid of lipid is combined with other nutritional-metabolic abnormalities, e.g. high cholesterol intake, induced diabetes mellitus, or other stresses *(26)*. These findings suggest that EFA need may be a function of the overall nutritional-metabolic situation of the organism. They suggest that—if an EFA deficiency does develop with ingestion of diets high in calories-fats-saturated fats-cholesterol (an unlikely possibility)—then it can only be a relative, secondary, derivative deficiency due to dietary imbalance.

NUTRITIONAL INTERRELATIONSHIPS

In addition to these studies on different fats, recent years have witnessed important experiments on the interrelationships between cholesterol-lipid and other nutrients (vitamins, minerals, amino acids) in atherogenesis.[h] For example, it was demonstrated that hypercholesterolemia and atherogenesis were apparently aggravated in cholesterol-oil-fed chicks permitted to ingest only 60% of their usual total feed intake, or subjected to intermittent starvation *(30, 31)*. Further, as already noted, it was shown that hypercholesterolemia and atherosclerosis could be successfully produced in monkeys and rats by utilizing a ration high in cholesterol-lipid and inadequate in the sulfhydryl-containing amino acid methionine *(25, 46)*. This phenomenon was amply confirmed in experiments in chicks (Figure 7) *(39)*. Other studies along similar lines demonstrated that feeding a ration low in choline also aggravated the hypercholesterolemic and atherogenic effects of a high-cholesterol, high-fat diet in rats.[i]

In other recent experiments it was further shown that hypercholesterolemia and atherogenesis were aggravated in cholesterol-oil fed chicks ingesting a diet low in total protein (Figure 8) *(40)*. It was also demonstrated that high-protein supplementation suppressed hypercholesterolemia and atherogenesis in cockerels ingesting a high-cholesterol, high-fat ration (Figure 9) *(40)*.

[h] One special facet of this research involves study of the effects of special supplements—e.g. plant sterols or brain extracts—to a high-cholesterol, high-fat ration. Each of these has been shown to produce a significant inhibition of hypercholesterolemia and atherogenesis. These experiments do not bear directly upon the problem of the influence of the main constituents of the diet on cholesterolemia and atherogenesis. Nevertheless, they are worthy of mention, particularly since they offer possible approaches to the therapy of hypercholesterolemia and atherogenesis in man *(20, 34)*.

[i] In contrast to these findings with deficiency of methionine and choline, experiments in recent years have tended generally to confirm previous extensive observations that supplementation of a nutritionally adequate ration with methionine, choline or other lipotropic factors fails to suppress hypercholesterolemia and atherogenesis *(19, 20)*.

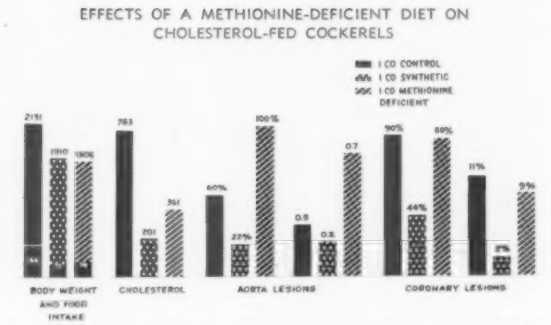

Figure 7. The 1 CO control group received regular chick mash supplemented with 1% cholesterol plus 5% cottonseed oil. The 1 CO synthetic group received a nutritionally adequate ration made up of purified components, including 1% cholesterol and 5% cottonseed oil. The 1 CO methionine deficient group received a purified ration identical with that of the preceding group, except that it was deficient in methionine.

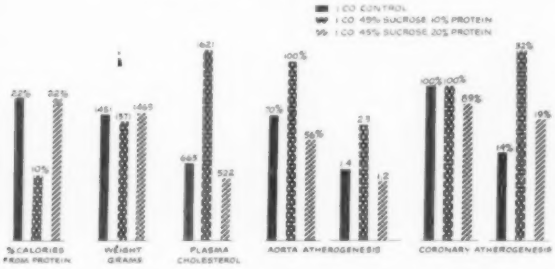
EFFECTS OF ADDITION OF REFINED CARBOHYDRATES TO HIGH-FAT, HIGH-CHOLESTEROL CHICK MASH—WITH AND WITHOUT REDUCTION OF DAIRY PROTEIN
1 CO CONTROL
1 CO 45% SUCROSE, 10% PROTEIN
1 CO 45% SUCROSE, 20% PROTEIN
% CALORIES FROM PROTEIN
WEIGHT GRAMS
PLASMA CHOLESTEROL
AORTA ATHEROGENESIS
CORONARY ATHEROGENESIS

Figure 8. All groups received mash supplemented with 1% cholesterol plus 5% cottonseed oil. In groups 2 and 3 45% of the ration was sucrose, which reduced the intake of protein and other nutrients. In group 3 purified protein was added to restore the protein content of the diet to a level equal to that of the control group.

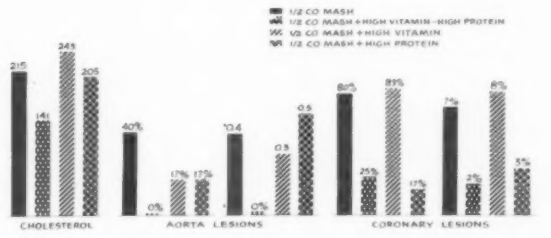

Figure 9. Effects of high-vitamin, high-protein vs. high-protein alone in cholesterol-fed cockerels, S-47—13-23 weeks.

Recent studies have also explored the effects of vitamin deficiencies in cockerels fed a potentially atherogenic diet. It was observed that chicks receiving a purified ration devoid of either biotin, inositol, para-aminobenzoic acid, or B_6, B_{12}, folic acid, exhibited intensified hypercholesterolemia and atherogenesis, especially when the high-fat, high-cholesterol diet was also low in protein. Preliminary findings indicate that deficiency of single vitamins—e.g. B_6, B_{12}—results in similar findings. These dietary interrelationships are being explored further.

In addition to the foregoing experiments on nutritional interrelationships, the last year or two witnessed the development of studies on the effects of trace minerals (e.g. vanadium, cobalt, magnesium) in animals on high-fat, high-cholesterol diets.[1] Work along similar lines is proceeding on the intertwined effects among specific carbohydrates, lipids and cholesterol.[1]

It should be emphasized that all these experiments on nutritional interrelationships involve analyses of the effects of specific nutrients (amino acids, lipotropic factors, proteins, vitamins, carbohydrates, minerals) in animals on high-fat, high-cholesterol diets. By demonstrating significant influences of some of these nutrients (e.g. proteins) these experiments lend support to the concept that the overall pattern of the diet—and nutritional imbalance—play a key role in the causation of hypercholesterolemia and atherogenesis. At the same time, their results reinforce the basic theoretical concept that high-fat, high-cholesterol intake is the decisive nutritional aberration in the etiology of hypercholesterolemia and atherogenesis.

PRODUCTION OF ATHEROSCLEROTIC COMPLICATIONS IN ANIMALS

Recent work has produced another significant advance in animal research on atherosclerosis. Until recently, no success had been achieved in efforts to produce the "complications" of the lesion, i.e. ulceration, thrombosis, tissue infarction. During the last year or two, some of these phenomena have been observed in rats and chicks receiving high-fat, high-cholesterol diets plus hormones *(15, 44, 45)*. This area of work is also being actively pursued at the present time.

REVERSIBILITY OF ATHEROSCLEROSIS

Another major contribution of experimental atherosclerosis has been the demonstration that the pathologic plaque is, within limits, a reversible lesion. This has been shown in rabbits, chicks and dogs *(3, 4, 19, 20, 41)*. Experiments on this aspect of the problem involved producing lesions by feeding an atherogenic diet. Upon discontinuation of this diet and substitution of a low-fat, low-cholesterol ration, hypercholesterolemia and atherosclerosis gradually regressed (Figure 10) *(41)*.

Reversal of atherosclerosis in the coronary vessels has also been achieved by another means—estrogen administration (Figure 11) *(37)*. Under the influence of this ovarian hormone, lesions regress even when the birds remain on the high-fat, high-cholesterol diet.

EXOGENOUS-ENDOGENOUS INTERRELATIONSHIPS

This last experiment serves as an appropriate reminder of the fact that this presentation has dealt

[1] For details and sources, cf. refs. *(30, 27, 28, 29)*.

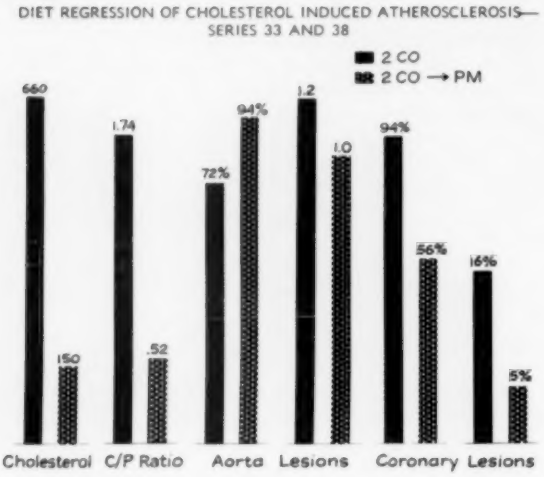

Figure 10. The symbol 2 CO —→ PM represents a transfer from a diet of 2% cholesterol plus 5% cottonseed oil (during the preceding 5 weeks) to a plain mash diet devoid of cholesterol and oil (for a period of 2 weeks). The solid black bar of each pair represents the value at the end of 5 weeks of feeding the diet supplemented with cholesterol and oil. The checkered bar of each pair represents the value after 2 weeks on plain mash, i.e. for a total of 7 experimental weeks. Regression of hypercholesterolemia and coronary atherosclerosis is demonstrated.

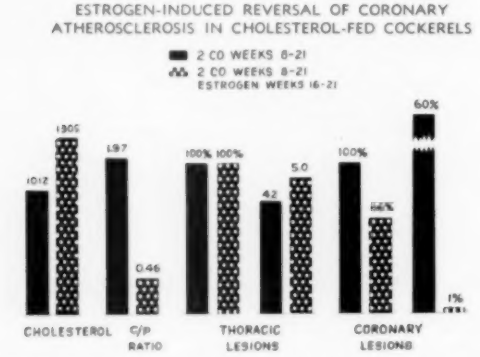

Figure 11. Both groups consumed mash supplemented with 2% cholesterol and 5% cottonseed oil throughout the experiments. The third group on a similar diet was sacrificed at 16 weeks of age to ascertain the extent of atherosclerosis at this juncture. This group is not illustrated on this graph; severe aorta and coronary lesions were observed. Beginning with the 16th week, the second group was given estrogens, and this was continued for the remainder of the experiment, with resultant disappearance of coronary lesions (but not aorta lesions).

almost exclusively with the influences of dietary (exogenous) factors on hypercholesterolemia and atherogenesis. The cited effect of estrogen—an endogenously secreted, physiologic hormone in the mature female—is an example (one among many from experimental atherosclerosis—cf. Figure 12) of a fundamental truth with respect to atherogenesis. A complex interplay occurs between exogenous and endogenous. *Given the long-term ingestion of a potentially atherogenic diet*, the nature of the organism —its genetics, heredity, sex, endocrinology, disease

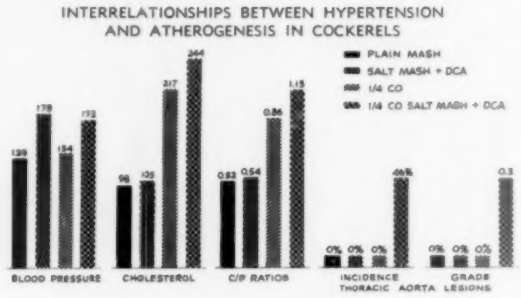

Figure 12. Note the absence of atherosclerotic lesions in group 2, given mash supplemented with salt plus parenteral desoxycorticosterone acetate (DCA), despite elevation of blood pressure induced by this regimen. Note also the absence of lesions in group 3, fed mash supplemented with ¼% cholesterol plus 5% cottonseed oil; this experimental regimen did not produce lesions in normotensive birds over a 15-week period. Note further that when the ¼ CO mash also contained salt and the animal received DCA (group 4), leading to a rise in blood pressure, aorta atherosclerosis was observed at the end of 15 weeks. Thus, hypertension aggravated atherogenesis in animals with the nutritional metabolic prerequisites for atherogenesis, but not in their absence.

history, etc., etc.—exerts an important influence. Thus, extensive data from experimental animals indicate that atherosclerosis has a multifactorial causation, with habitual diet—the *sine que non*—a key factor, interacting with other factors.

CONCLUSION

In conclusion, it is appropriate in such a symposium to attempt a tentative interpretative extrapolation of the significance of the animal experimentation for the problem in man. One basic fact stands out: The overwhelming success achieved in producing atherosclerosis in every important laboratory species—a success achieved primarily by dietary means involving the addition of fat and cholesterol to the diet—is a major piece of evidence which cannot be ignored. From this experience in rabbit, chick, rat, dog, monkey, etc., it would seem valid to conclude that man is in all likelihood not decisively exceptional—i.e. that diet, dietary fats and cholesterol, play an important role in the pathogenesis and etiology of atherosclerosis in man as well.

Acknowledgments

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Radiation of Important Grain-Infesting Pests:

Order of Death Curves, and Survival Values for the Various Metamorphic Forms[a,b,c]

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THE RECORD of application of ionizing radiations to insects with the object of deinfestation dates back nearly to the discovery of X-rays in 1895 *(7)*. The record of the damage inflicted on grain and grain products by grain-infesting pests is more venerable, and extends far back into history. Today, in the United States, even the most conservative estimate places the loss at 5% of the annual grain production *(12)*. The value of the lost product combined with the cost of measures to combat these pests brings the annual bill to $300,000,000 *(3)*.

Among early papers on the application of ionizing radiations to insects are those of Runner *(11)* and Davey *(4)*; these men revealed most of the facts known today about the nature of insect death from radiation. More recent papers extending the knowledge of radiation treatments to insects, inspired by the existence of the more powerful particle accelerators and radioactive sources, are: Youmans *(13)*, Hassett and Jenkins *(6)*, Baker *(1)*, Proctor, Lockhart, Goldblith, Grundy, Tripp, Karel, and Broglé *(9)*, and Cornwell, Crook, and Bull *(2)*.

Almost without exception, principally in the work of Cornwell *et al. (2)*, the insects previously treated have all been killed, regardless of the metamorphic form treated. In the present study, more attention was given to sub-100%-lethal doses in an effort to provide not only some clue as to the order of death of the irradiated insects, but also some basis for comparison among species, and to determine from these facts recommendations for the application of ionizing radiations for actual deinfestation. A second important reason for investigating low doses is the advisability of keeping produce damage to a minimum. A previous paper, Nicholas, Meiske, Jones, Wiant, Pflug, and Jones *(8)*, presented data showing that flavor changes become evident at rather modest radiation doses (about 50,000 rep) in bread made from irradiated flour and flour milled from irradiated wheat.

EXPERIMENTAL

Twelve pest species were studied, including the four most important primary insect pests and two of the most important secondary insect pests. Table 1 gives the scientific and common names of these pests.

TABLE 1
Pests irradiated

Scientific name	Common name
Ephestia kühniella Zell	Mediterranean flour moth
Oryzaephilus surinamensis (L.)	sawtoothed grain beetle
Plodia interpunctella (Hbn.)	Indian-meal moth
Rhyzopertha dominica (F.)	lesser grain borer
Sitophilus granarius (L.)	granary weevil
Sitophilus oryza (L.)	rice weevil
Sitotroga cerealella (Oliv.)	Angoumois grain moth
Tenebrio molitor L.	yellow mealworm
Tenebriodes mauritanicus (L.)	cadelle beetle
Tribolium confusum Duv.	confused flour beetle
Psocoptera [1]	book lice
Acarus siro (L.)[2]	flour mite

[1] Order only known.
[2] Probable identification.

All the radiations in this work were performed with a General Electric 1-Mev electron-beam generator operated at the peak voltage of 1 Mev. All insects were reared and housed in the rearing rooms of the Entomology Department or in an incubating cabinet in the Agricultural Engineering Department. In all cases, the control (non-irradiated) samples were subjected to the same treatment, exclusive of radiation, as the treated samples, even to the extent of placing them in the same kind of container and subjecting them to the same conveyor handling as the irradiated samples. The elapsed time between radiation and returning the insects to the rearing rooms was kept to a minimum, consistent with the demands of transporting the samples ¼ mile across campus. In the winter samples were put in insulated boxes to avoid excessive temperature changes during transport. Dosimetry was determined from ionization chamber measurements. The thickness of infested food contained in any one sample was determined, in the case of oatmeal and flour, by the penetration restrictions of 1-Mev electrons. For wheat and corn, only a one-kernel layer was treated. After a few tests with corn, it was abandoned in favor of wheat, which more nearly conforms to penetration restrictions. As a result of this change of food, the Angoumois grain moth, the only insect raised in corn, was smaller in size, characteristic of these moths raised in wheat, but the vigor of the colonies was in no way reduced. In fact, the number of second-generation adults from isolated pairs of non-irradiated insects exceeded the reported averages of number of eggs laid by this species. Because some of these pests cannot be raised, or prefer not to be raised, outside whole kernels of grain, and because the criterion of deinfestation was taken to be failure of the insect species to be perpetuated beyond the first, irradiated generation, the results were analyzed in terms of the number of adults that emerged from irradiated immature forms compared with the number emerged from controls rather than, for example, the fraction of eggs failing to eclose, or the number of irradiated larvae that failed to pupate. Both death and sterility of the adults were determined.

Analysis. Two features of order of death were observed: first, the reduction in survival against dose; and, second, the survival against time of a single population. The first order of death was determined by radiating a number of populations at various doses and determining the survival at a time long after treatment, long compared to the time taken to deliver the treatment (about 20 days or more, depending on the species). The second order of death was determined by radiating single

[a] Journal Paper No. 2265, Michigan Agricultural Experiment Station, East Lansing, Michigan.

[b] Presented before the Eighteenth Annual Meeting of the Institute of Food Technology, Chicago, Ill., May 28, 1958.

[c] This research is a portion of a thesis presented by R. C. Nicholas as partial fulfillment of the requirements for the Ph.D. degree in Agricultural Engineering at Michigan State University.

cultures (principally adults) and making periodic counts to determine survival. The data are corrected for the natural mortality of the controls. The choice of abscissa is suggested by the nature of the response observed of the insect system: either the subject dies or it does not; either a live adult appears or it does not; therefore, the results will be binomially distributed and, therefore, normal coordinates were used for the per cents of survivors for both orders of death. In the case of the first kind of order of death, plots of survivors were made on log-probability paper, as suggested by Finney *(5)*. For the second kind of order of death, survivor curves were made on arithmetic probability paper, as suggested by Rahn *(10)*.

RESULTS AND DISCUSSION

Either the best, most consistent results, or ones most illustrative of a particular phenomenon have been chosen to represent the various metamorphic forms: egg, larva, pupa, and adult. The results not presented, although less striking, usually because of small numbers, do not in any instance invalidate the general trends indicated by the figures presented.

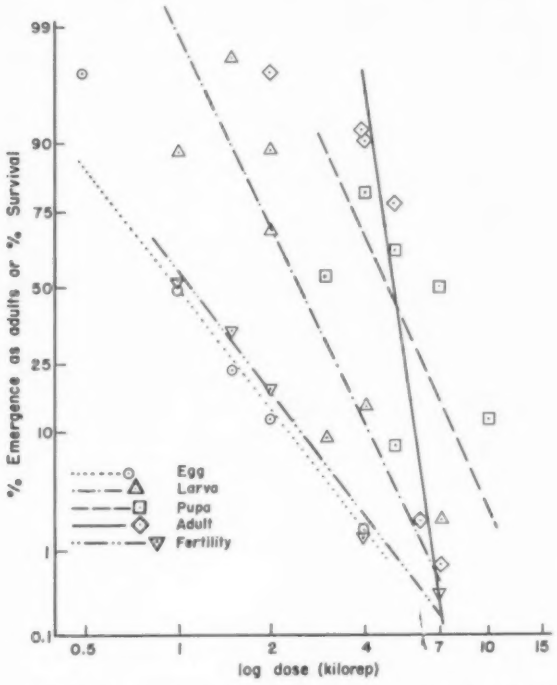

Figure 1. Emergence or survival of the metamorphic forms of irradiated confused flour beetle.

Figure 1 shows the results from a number of tests with the confused flour beetle, *Tribolium confusum*. This insect is easy to work with because although it can fly, it very seldom does; it cannot climb out of glass containers; it is more amenable to less-than-optimum rearing conditions; and the pupae and larvae live in loose material rather than inside a single kernel. Therefore, all 4 forms can be readily worked with and observed. The difference to be expected between metamorphic forms shows up readily for eggs, larvae, and pupae. The eggs were radiated immediately after a 3-day laying period, the larvae at about the 0.5-completed point in the larval stage, and the pupae in the first third of the pupal stage. The fertility curve of Figure 1 shows the number of second-generation adults that emerged from eggs laid by adults radiated at the stated dose. The 2 curves for which the scatter of plotted points is least (eggs and fertility) are based on controls of about 500 insects; the larva and pupa curves, in which the scatter is greater, are based on initial populations of about 20 to 30 subjects; the fifth curve, adults, is based on initial populations of about 150 insects. These curves are representative of the first kind of order of death. Another point that should be made is that while these emergence values are based on the number of adults that emerged, it does not follow that such adults are the biological equals of adults from non-irradiated immature forms. Other tests have shown that these adults have a shorter life expectancy and a lower fertility, so that recommended applications based on mortality figures such as these will have a quantitatively unknown, built-in safety factor.

Figure 2 shows the survival pattern of irradiated Mediterranean flour moth larvae. These larvae were radiated at about the 0.5-completed point of the larval stage. The curve for the control larvae represents the pupation, emergence as adults, and subsequent death of these moths, the normal life span of which is about 2 weeks. The curves for larvae irradiated at 10,0000 and 20,000 rep show the prolongation of life by irradiation. Only two of these irradiated larvae pupated and emerged as adults, both were radiated at 10,000 rep. Only at 40,000 rep was the normal larval period reduced, although emergence was appreciably reduced by the much lower dose of 10,000 rep. These larvae were probably feeding very little and their activity was much reduced, as evidenced by the near-absence of the dense webbing characteristically left by these larvae.

Figure 3 shows the emergence and survival pattern of irradiated sawtoothed grain beetle pupae. The radiation does not appreciably affect the time of emergence, nor the time at which the irradiated forms that are to die do so. These data illustrate the principle previously mentioned that survival of adults from irradiated immature forms is below normal and that

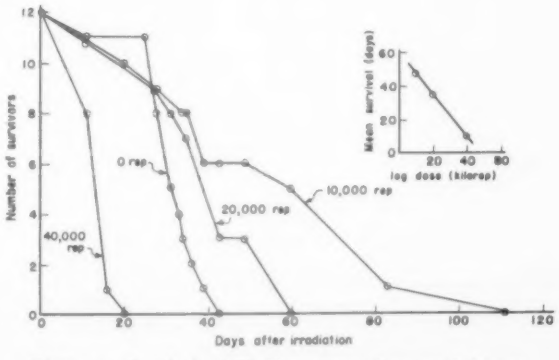

Figure 2. Survival of Mediterranean flour moth larvae.

fertility is reduced. The point at which emergence is reduced by 50% is about 5,000 rep, but the point of 50% survival (here defined as survival through the 18th day after irradiation) is about 3,000 rep. The samples were kept until second-generation adults emerged in the control samples. None of the irradiated samples showed any second-generation forms.

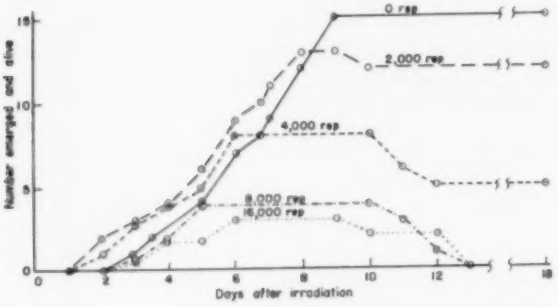

Figure 3. Emergence of irradiated sawtoothed grain beetle pupae.

Figure 4 shows an interesting feature of functional fertility of irradiated lesser grain borer adults. Groups of 30 adults each were radiated at a series of doses increasing by a factor of two. While the beetles were dying they were transferred to new, uninfested wheat every 3rd day. The figure gives the number of second-generation adults produced for each first generation adult still living in the successive three-day periods. It has been suggested that the initial low fertility shown by all 3 samples is a result of the shock to the insect system of handling and irradiation. The adults radiated at 8,000 rep and above had no offspring. This gradual loss of fertility was exhibited by the two other species (the granary weevil and confused flour beetle) in which the tests were conducted in such a way as to bring out the fact.

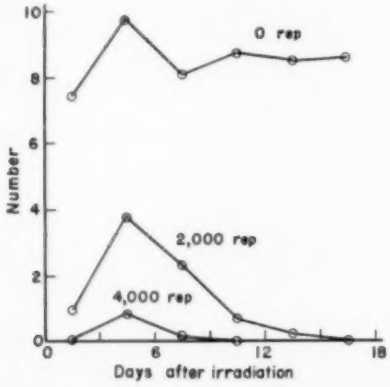

Figure 4. Number of 2nd generation lesser grain borer adults per irradiated 1st generation adult produced in successive 3-day period.

Table 2 is a summary of the evidence gathered on the metamorphic forms of 9 of the species studied, presented as LD_{50}'s; that is, the reduction, compared with the controls, in number of emerged adults from the given irradiated immature form. If a single value appears in the table, it was determined from a log-normal plot similar to Figure 1. When ranges are given, either one or both of the points was 100% or 0% emergence, and, therefore, impossible to plot on probability paper. The sterility values of the Angoumois grain moth, for example, show another interesting aspect of the effect of radiation on functional sterility. These moths were radiated as mating pairs and kept in separate containers. Two kinds of data were collected: the number of fertile pairs, and the total number of second-generation adults from each fertile pair. In the test reported, all the adults radiated at 10,000 rep, the lowest dose, were fertile, but the average number of second-generation adults was only 17 a pair (range: 3–42) compared with an average of 128 for the control pairs (range: 84–156). The pairs treated at 40,000 and 160,000 rep were all functionally sterile. Forty-thousand rep failed to reduce the length of life of these moths, which is about one week.

TABLE 2

Mean emergence as adults of irradiated metamorphic forms, and sterility of irradiated adults (LD_{50} in rep)

Species	Egg	Larva	Pupa	Adult	Sterility
Ephestia kühniella	.....	5,000	6–10,000	.....	10–20,000[1]
Oryzaephilus surinamensis	<2,000	2–4,000	5,000	8,000	6–8,000[2]
Plodia interpunctella	.....	5–8,000	<25,000	.....	.....
Rhyzopertha dominica	<2,000	<4,000	.....	7,400	4–8,000[2] <2,000[3]
Sitophilus granarius	1,300	2,200	.....	<5,000	5–10,000[2] <5,000[3]
Sitophilus oryza	<2,000	1,200	.....	<10,000	<10,000[3]
Sitotroga cerealella	7,500	8,000	.....	.....	10–40,000[1] <10,000[3]
Tenebrio molitor	.....	<20,000	.....	.....	.....
Tribolium confusum	970	2,500	4,800	5,000	4–7,000[2] 1,100[3]

[1] 50% pairs sterile.
[2] Fertility-sterility range.
[3] 50% reduction in second generation.

The results from 3 species investigated do not appear in Table 2. The cadelle larvae results could not be analyzed in the same manner as the other insects because excessive cannibalism in the control larvae obscured the natural mortality factor. Figure 5 shows the survival pattern of control and irradiated larvae. These data are the combination of four 20-larvae replicate samples at both 0 and 100,000 rep. The mortalities are significantly different (5% level) at each plotted point except at 8 days (near the cross-over point of the curves). The orders of death are different. Most of the deaths in the controls can be attributed to cannibalism.

Data on mites and book lice were obtained from heavily infested cultures of unknown initial number

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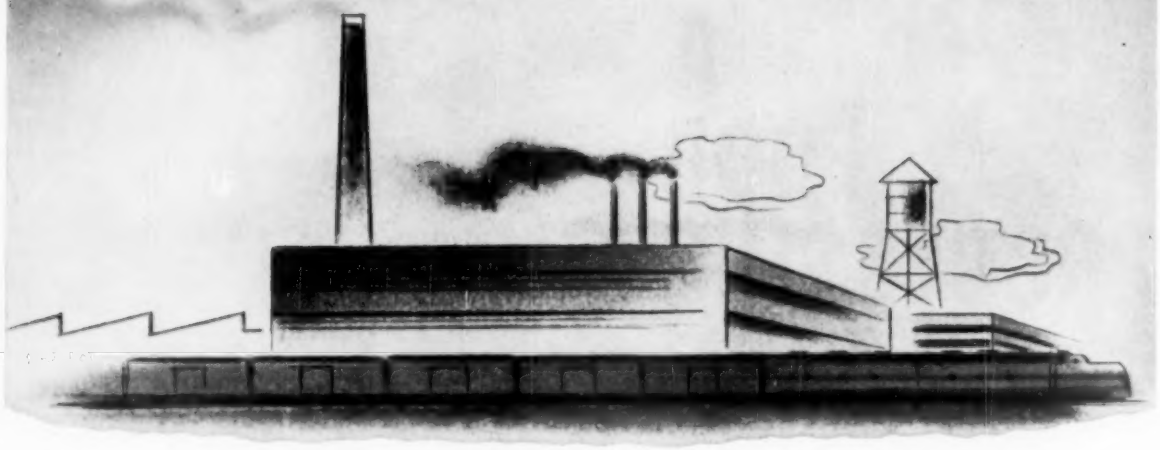

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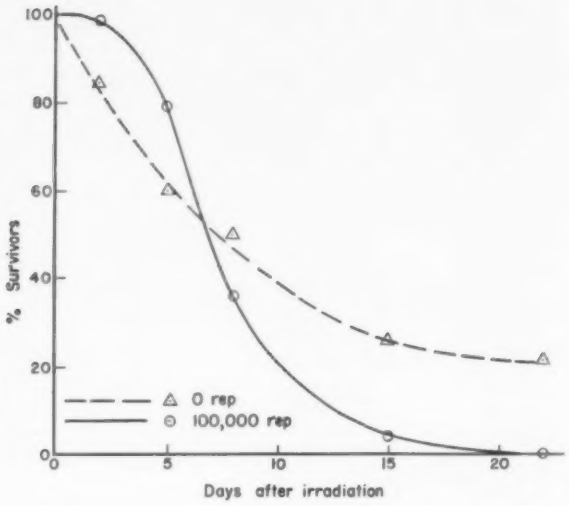

Figure 5. Survival of irradiated and non-irradiated cadelle larvae.

and metamorphic form distribution, so that nothing is known of the actual population reduction at the various doses. Mite colonies survived at doses of 80,000 rep and below, but appeared to be killed by doses of 90,000 rep and above; however, the results were obscured by reinfestation of the samples. Book lice colonies survived 30,000 rep, but not doses of 50,000 rep and above.

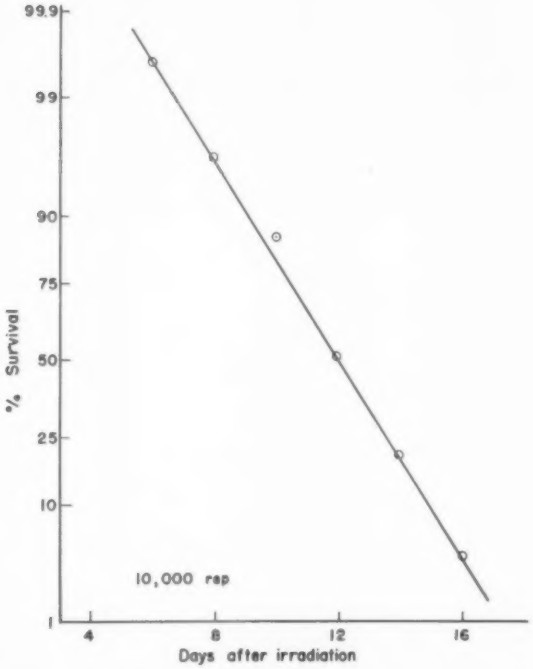

Figure 6. Order of death of irradiated confused flour beetle adults.

Results (Table 2) suggest differences among species, graduated resistance within a species increasing with age of the insect, and a more marked difference between the 3 moths and 5 beetles. The LD_{50} for larvae, for which complete data are presented, show a range for the moths of 5–8,000 rep compared with a range of 1,200–4,000 rep for the beetles (the yellow mealworm must be excluded since an upper limit only is known). The corresponding 99.9%-lethal doses are about 40,000–60,000 rep (moths) and 10,000–20,000 rep (beetles).

Figure 6 is an example of the second kind of order of death, a plot of survival against time for 284 adult confused flour beetles all radiated at 10,000 rep. The jars in which these dying beetles were kept were saved for sterility observation; no second-generation forms were found. All insects treated at near-100%-lethal doses exhibited survival curves of precisely the same form.

SUMMARY

Twelve grain-infesting pests, including a non-insect species, were treated with 1-Mev electrons at various doses to determine the lethality of the treatment to the metamorphic forms and to determine sterility effects upon adults. Order of death curves of survivors against time, where obtained, verify the sigmoid shape of the curve; in general, graded resistance within a species is exhibited increasing with development stage of the insect from egg to adult. Of the insect species, the three moths showed the highest radiation resistance, compared with the beetles. Pests covered by the study include: confused flour beetle, rice and granary weevils, sawtoothed grain beetle, cadelle, Angoumois grain moth, Indianmeal moth, Mediterranean flour moth, lesser grain borer, yellow mealworm, a mite, and a psocid.

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Procedures for Determining Grades of Raw Tomatoes for Processing[a,b]

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(Manuscript received May 31, 1958)

The problem of evaluating the quality of tomatoes for processing has been studied extensively for many years with particular attention being given to the possibility of improving existing U. S. grades by relating them more closely to the quality of the finished product *(2, 3, 10, 11, 12)*. It was contended that existing grades are specifically deficient in that they rely on subjective methods, and that they do not necessarily reflect the value of the tomatoes as raw material for a manufactured product. The procedures proposed in this paper are based on studies conducted at the Maryland Experiment Station in cooperation with other agencies and tomato processors during the past eight years.

SAMPLING

In a study reported previously *(9)*, it was determined that a sample consisting of a total of 100 tomatoes removed at random from 10 hampers selected randomly from a lot, (or a multiple thereof, depending on the precision required), constituted the most economic means of obtaining an efficient sample. This method was approximately half as costly as the existing method of utilizing the entire contents of a given number of baskets for grade inspection.

The difficulty of obtaining ten tomatoes at random from a basket may be overcome by the use of a sampling device; one such sampler is under construction at the University of Maryland.

Following the generally accepted procedure of increasing sample size with increasing lot size *(13)*, in order to reduce the risks caused by the size of the sampling error, the following schedule is suggested:

TABLE 1
Sampling schedule for lots of tomatoes of different size

Lot size		Sample size		Per cent error (2 Sigma)
Tons	Hampers	No. baskets	No. fruits	
up to 5	to 300	10	100	4.5
5 to 10	301–600	20	200	3.2
10 and over	601 and over	30	300	2.6

The decision as to how big a sample to take, thus depends on the precision desired, and can be established by management. This decision can be based on calculations such as the following: Assuming a value of $.02 per pound of usable tomatoes, the risks involved in terms of possible overpayment for different lot sizes may be calculated as follows:

TABLE 2
Sampling costs and risks of overpaying for different lot sizes

Sample size, No. of fruits	Sampling cost	Risk for lot sizes, in tons		
		up to 5	5–10	over 10
100	$2.00	6.75	13.50	22.50
200	4.00	4.80	9.60	16.00
300	6.00	3.90	7.80	13.00

Thus it may be noted that doubling the sample size from 100 to 200 fruits is not compensated for entirely by a respective reduction in risk for lot sizes under 5 tons, but is more than compensated for with lots of over 5 tons. Similarly, an

[a] Scientific article No. A696. Contribution No. 2919 of the Maryland Agricultural Experiment Station (Department of Horticulture).

[b] Presented at the Eighteenth Annual Meeting of the Institute of Food Technologists, Chicago, May 28, 1958.

additional increment of 100 fruits in sample size is not worth while until a ten ton lot size is reached.

It may be argued that an unbiased inspection error may be to the benefit as well as to the detriment of the processor. On the other hand it should be noted that a precise sample is of value not only in arriving at more equitable prices, but also in providing information on the nature of the raw material which should be of considerable value in subsequent plant operations.

ASCERTAINING THE GRADE

In handling the sample for ascertaining the grade, it has been shown *(7, 17)* that in a determination of color quality particularly if the tomatoes are to be manufactured into any products other than whole tomatoes, the sample should first be comminuted and color determined on the juice blend, rather than on individual fruits. For a determination of defects other than color that may require trimming, or may render the fruit entirely unusable (cull), it is necessary to evaluate each fruit individually.

For a reasonable estimate of the value of the lot, it is therefore necessary to handle the defects and color factors separately. In this procedure it is proposed that the unusable fraction of the lot represented by culls and trimmings be handled as a deduction from the net weight of the lot, and the quality grade be based on a color evaluation, supplemented by size and solids determinations only when needed.

Defects. Defective tomatoes may be classified into two categories. The first, which will be called "culls," are such tomatoes that are considered worthless, and must be discarded, since the required amount of trimming would not leave enough usable tomato tissue to make the trimming operation worthwhile. Photographs and other visual aids have been developed by the U. S. Department of Agriculture to aid the inspector in determining the limits for culls. In this procedure, the per cent by weight of culls is multiplied by a factor of 1.1 and the product is used as a per cent deduction (Figure 1). The factor of 1.1 is used in order to compensate for the labor involved in culling out this material.

The second type of defect is one which is not so extensive as to render the entire fruit useless, but some trimming is required.

A study of the relationship between the per cent count of tomatoes requiring trimming and the actual per cent of trimmed weight revealed a highly significant correlation of .84, thus indicating that a mere count of tomatoes requiring trimming is a good indication of loss of material due to trimming. The relationship was curvilinear, as shown in Figure 2. Thus, when only a small per cent of the tomatoes require trimming, as for instance 10%, trimming weight loss on these tomatoes is only 5%. However, as the number of tomatoes requiring trimming increases, the per cent of material trimmed increases, so that when 80% of the tomatoes require trimming, their weight loss is about 10%, or twice as high. This is entirely logical since it is readily understandable that in lots

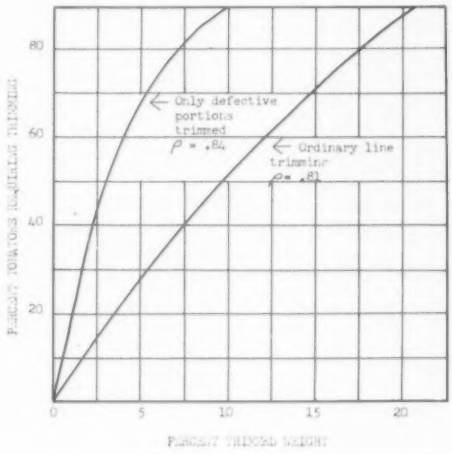

Figure 2. Relation of per cent tomatoes requiring trimming to per cent trimmed weight.

of tomatoes in which very few units require trimming, the defective material is less extensive than is the case when many fruits are defective and the defective areas in the fruit are more extensive.

When similar studies were conducted under actual plant operating conditions, results obtained were similar in that the correlation between defect counts and weights was .81. The regression line fitting this relationship however, was decidedly closer to a straight line, and averaged about 20% loss in weight due to trimming instead of 6% when the trimming was done with special care to remove only the defective portions. These studies indicated that in ordinary line operations, any tomato which is trimmed by plant personnel, is trimmed to approximately the same extent, that is, about one fifth of the tomato is removed regardless of whether the defective portion approaches that quantity, or whether it is considerably less.

RAW TOMATO GRADING FORM

PLANT: College Park — DATE: Aug. 1, 1957

LOAD OR LOT NO.: 101 — GROWER: H. S. Todd — BROKER: _____

GROSS WT.: 28,500 — VEHICLE & CONTAINER WT.: 9,600 — NET WT.: 18,900

GRADE		DEDUCTIONS	WEIGHT OR COUNT	PERCENT
Time sampled: 10 A.M.		Load net weight	18,900	100.0
Time graded: 11 A.M.		Sample weight	68.5	100.0
Color quality:		Sample count	200	100.0
L: 27.5		Cull wt. 3.64 (x1.1)	4.00	5.8
a: 26.2		Trimming count 24 (x.33)	8	4.0
b: 10.9		Total deductions		9.8
COLOR GRADE SCORE: 96		USABLE LOAD WEIGHT	17,157	90.8

REMARKS: _____

Lee
INSPECTOR

Figure 1. Grading form for raw tomatoes.

It was therefore concluded from these trimming studies, that a count of tomatoes requiring trimming would provide essentially as much information as actual weights of trimmed material, and that about 20% of a tomato requiring trimming would be lost in the trimming operation.

Assuming a value of $.02 per pound of usable tomatoes, it was estimated that the cost of trimming a tomato was equivalent to 13% of its value. Thus, adding a 13% deduction for the cost of trimming to the 20% weight loss, it may be concluded that a tomato requiring trimming is worth only two thirds of a sound tomato. Hence, in this procedure, the per cent count of tomatoes requiring trimming is divided by three (or multiplied by .33), and this value is used as a second deduction from the total net weight (Figure 1).

Color. Much attention has been devoted to the measurement of color of tomatoes *(1, 4, 8, 11, 12, 14, 16, 17)*. It is generally agreed by many workers that evaluation of tomato color by visual inspection is not satisfactory, since individual inspectors, operating without reference guides tend to drift towards an average evaluation so that consistently high quality material is downgraded, and consistently poor material is upgraded *(18)*. Because of variable weather conditions, varieties etc., surface color is not necessarily a good index of internal color *(12)*. Color plates, models, are not satisfactory because of the multidimensional nature of tomato color *(5, 7)*.

Of the objective methods and instruments proposed for color measurement of tomatoes, Munsell discs *(1, 11)* and Hunter a/b ratios *(2, 5, 12, 17)* appear to be acceptable from the color theory standpoint. Munsell discs are used widely for the measurement of color of the finished tomato products, and the Hunter color difference meter is coming into more general use. A nomograph for determining color grade scores for tomato juice was developed and presented previously *(5, 8)*. More recently, in a study involving a number of laboratories, it was found that color evaluation of the same samples by different laboratories all using the Munsell system, varied by as much as two grade points. Different Hunter color-difference instruments, *properly calibrated*,[b] exhibited differences of less than one grade point *(4, 14)*. Furthermore, since the Munsell disc method even when provided with a satisfactory light source *(16)* requires a final subjective matching of color, the entirely objective, properly calibrated, Hunter instrument is to be preferred. Where equipment cost is a factor, it may be possible to use less expensive color instruments, but at a sacrifice in precision.

Previously conducted studies at the University of Maryland have also indicated theat color loss in processed tomatoes is due practically entirely to the application of heat during the manufacture *(8)*, and when properly controlled, this color loss resulting from the manufacturing process can be limited to little more than 3 grade points *(3)*. Since the present grade for canned tomato juice consists of a maximum of 30 points for color then raw tomatoes having a hypothetical score of 33.3 should pack out with a maximum grade for color. Thus the nomograph shown as Figure 3 was prepared from the one originally developed for canned tomato juice, with additional lines to provide values up to 33.3. When these grade score points are multiplied by 3, we obtain a scale with 100 points which may be used for the purpose of grading color quality of raw tomatoes for processing. Thus on this scale, raw tomatoes grading up to 76 may be expected to yield a substandard juice, 77–85, standard, and 86 to 100, fancy tomato juice. A sliding scale for payment on a grade basis may then be constructed in a logical manner, taking into account the effect of color quality on the price offered for the finished product. A method for constructing such pay scales is presented elsewhere for lima beans *(15)*, and sweet corn *(6)*.

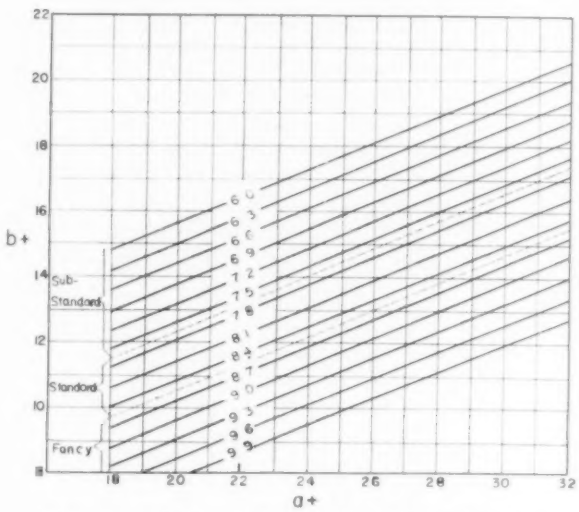

Figure 3. Relation of Hunter "a" and "b" values to raw tomato color grade score.

Other quality factors. Particularly for the manufacture of whole tomatoes, size could be an important consideration in the overall grade. An evaluation of average tomato size could be readily obtained from the data shown in Figure 1, by dividing the sample weight by the sample count. The quotient would thus be the average weight of one tomato in terms of pounds.

In the manufacture of concentrated tomato products such as paste and ketchup, total solids could well be of substantial economic importance. In such instances a measure of specific gravity and/or refractive index should be added to the grading procedure, and incorporated in the pay scale.

[b] To calibrate a Hunter color-difference meter for tomato color measurements, it is absolutely essential to set the instrument with a reference tile well within color specifications for typical tomato products *(4)*.

SUMMARY OF GRADING PROCEDURE

The procedure for ascertaining the grade of raw tomatoes for processing consists of filling out forms such as the one illustrated by Figure 1, as follows:

1. Obtain a representative sample of raw tomatoes by removing at random 10 tomatoes from each of 10 baskets, or a multiple thereof if greater precision is desired. (see Table 1).
2. Inspect each tomato and sort out the culls. Culls may be of two types: (a) color—This may be determined with the aid of USDA photographs; (b) other defects—Such fruits that are so highly contaminated and/or cracked and otherwise defective, that they are worthless. Weigh the culls, multiply by 1.1, and report as a per cent deduction.
3. Count the number of tomatoes requiring trimming, divide by 3.0, and report as a second per cent deduction.
4. Comminute the sample, excluding the culls, in a laboratory size pulper-finisher, mix thoroughly, deaerate if necessary, and obtain "a" and "b" values on a *properly calibrated* Hunter color difference meter. Convert these "a" and "b" values to the color score by reference to Figure 3.
5. Calculate the usable load weight, and pay for that quantity on the basis of the color grade score.
6. Where necessary, determine average tomato size by dividing the sample weight by the sample count, and tomato solids by determining specific gravity and/or refractive index of the pureed sample, and include these data in the grade evaluation.

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Fats Make Good Foods — Where and Why Are the Margins?*

(Manuscript received June 19, 1958)

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The Nutrition Foundation, Inc., New York, N. Y.

THERE ARE MANY REASONS why fats have a conspicuous place in human diets. First, they are associated with good flavors and concentrated energy. Second, they are normally associated with sources of good protein, and these have long been recognized as of crucial importance in relation to human health, as illustrated by meat, fish, milk, eggs and oil-bearing seeds. These foods are also characterized by a high content of vitamins and minerals.

In parallel with rapid progress in the science of nutrition during the past half century, fats were recognized as important carriers of vitamins A, D, E and K, together with fatty acids that are now commonly recognized as essential for optimum nutrition in a broad sense, and of distinct value in human nutrition.

With the advent of quantitative studies related to a sense of satiety at a single meal and the need to maintain satisfactory intervals between meals, without stress from periods of hunger, fats have also been recognized as contributing to desired physiological balances and time cycles for eating.

OPTIMUM RANGE OF FAT INTAKE

Relatively few long-term studies have been conducted to gain an appraisal of the optimum range of fat intake in terms of calories, either in animals or in man. The work with rats by Dr. R. W. Swift and others at Pennsylvania State University, by Dr. H. J. Deuel and his group at the University of Southern California, and by Professor H. C. Sherman at Columbia University, gave substantial evidence of a relatively high tolerance of fats, both saturated and unsaturated, on a life-span basis.

In the case of human populations most of the studies have been of an observational nature during periods when so many unknown or variable factors were at play, that the evidence at best was scarcely satisfactory to most students of either nutrition or public health. Nevertheless, if we use a common sense appraisal of human experience, relatively satisfactory levels of health have been maintained through many centuries among populations ranging from approximately 10% of total calories as fat, in many tropical and subtropical areas, to approximately 80% of total calories among populations living in arctic regions. There are two major weak spots in these observations of extreme dietary practices however; first, the vital statistics are not satisfactory in terms of public health; and second, the dietary records are incomplete, reflect many variables, or are inadequate in other respects.

Nevertheless, the evidence in human experience is reasonably consistent with such evidence as we have from research, in which mammals were used as experimental animals. From the most cogent tests with rats, for example, and such implications as these may have for human health, fat intakes within the range of 25 to 45% of total calories appear to be within a satisfactory and safe range, if the composition of the fat and the balance of the diet are reasonably satisfactory. This generalization is meant to apply to normal populations whose health, food practices, and general environmental conditions are within common ranges of experience. Obviously, individual problems and extremes of environmental experience must be considered according to the circumstances.

In view of the present average consumption of fats in American diets, in the range of 35 to 45% of total calories, there does not seem to be substantial evidence that this range of intake is likely to be injurious to normal individuals if their diet is otherwise balanced with respect to total calories and to specific nutrients. The adjustment of caloric intake to caloric need, and the composition of the fats consumed represent areas of greater practical interest than the per cent of calories derived directly from the fat eaten.

FIRM RECOMMENDATIONS ON DIETARY CHANGES NOT YET POSSIBLE

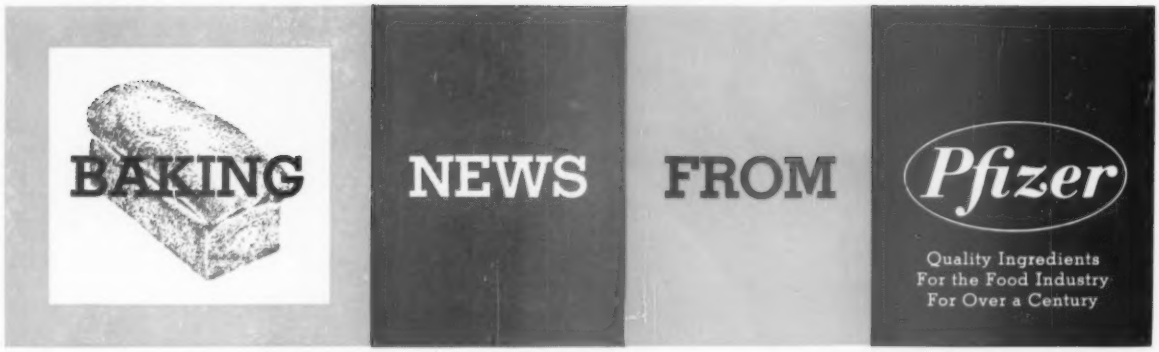
After very careful study by an impartial committee representing both medical and non-medical nutrition sicentists, a recent report issued by the Food and Nutrition Board of the National Academy of Sciences—National Research Council summarizes the evidence as follows: "Results of recent studies are valuable and thought-provoking, but they do not give sufficient data to make firm recommendations on dietary changes. Caution is necessary in accepting bits of experimental data before the entire picture is clear.

"The American diet is believed to be as nearly adequate as any enjoyed by civilized man. It is rich in high-quality protein, vitamins, and essential minerals. Its fat content is also rather high.

"Until it is clearer which fats are more desirable nutritionally and which, if any, are undesirable major changes in American dietary habits are not to be recommended.

"There is nothing in the history of nutrition that should persuade man to give up reasonableness and moderation in his choice of foods. Above all, there is need of judicious and accurate interpretation of

* Presented at the Symposium on Fats in Foods, Eighteenth Annual Meeting of the Institute of Food Technologists, Chicago, May 29, 1958.



NEW INTEREST IN GLUCONO-DELTA-LACTONE AS ACIDULANT IN "INSTANT" DOUGH MIXES PERMITS BREAD PRODUCTION IN 50 MINUTES INSTEAD OF 5 HOURS.

Currently, the baking industry is evaluating new chemical leavening systems which contain glucono-delta-lactone. Following the presentation of reports at a meeting of the American Association of Cereal Chemists and Institute of Food Technologists by scientists from the Quartermaster Food and Container Institutes, many companies are evaluating new markets for products containing glucono-delta-lactone.

The reports deal with an "instant" bread mix containing glucono-delta-lactone as the acidulant. With this mix no conventional yeast fermentation and proofing steps are needed . . . chemical leavening permits production of finished bread in 50 minutes as compared to approximately 5 hours for a yeast-leavened loaf. The bread has standard shape, color, grain and texture. Moreover, this bread does not have the objectionable aftertaste found with some leavening salts.

In addition to its use in bread mix, glucono-delta-lactone has proven effective as the acidulant in prepared cake mixes, angel cake, pound cake, biscuits and roll mixes. In laboratory evaluations, Pfizer Technical Service found that the slow hydrolysis rate of glucono-delta-lactone in cold water coupled with an increased hydrolysis rate at elevated temperatures make it an excellent acidulant for baked products which can utilize a chemical raising action.

Fumaric Acid & Cream of Tartar

Other interesting Pfizer acidulants for use in chemical leavening systems are fumaric acid and cream of tartar. Both of these products have limited solubility in cold water which inhibits the reaction with bicarbonates with a resulting small evolution of gas during initial stages of mixing. An increase of solubility at elevated temperatures results in major carbon dioxide evolution at baking temperatures.

New Pfizer Sorbistat®-K

Sorbistat-K overcomes the problem of water solubility of sorbic acid. Up to 40% solutions can now be prepared rapidly by simply dissolving in water. Because of this improved solubility many companies have found in recent experience that the new potassium salt has proved more effective than the acid.

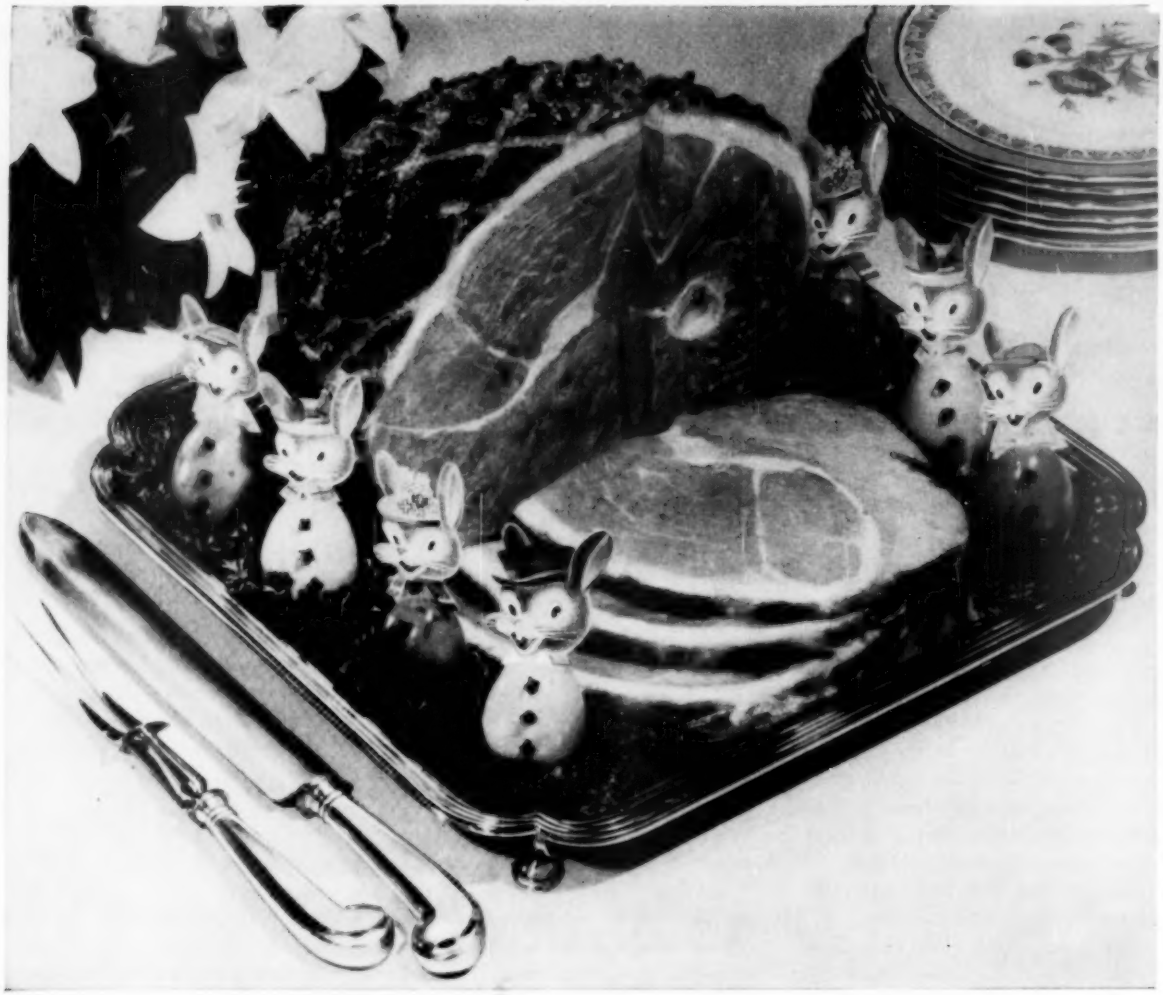
Both Sorbistat (sorbic acid, Pfizer) and its water-soluble potassium salt, Sorbistat-K (potassium sorbate, Pfizer) are effective growth inhibitors for many yeasts and molds which cause spoilage of baked goods.

Generally, Sorbistat and Sorbistat-K are effective at pH 2.0-7.0. In the baking industry, Sorbistat-K is the product of choice in chemically-leavened baked products due to its wide range of effectiveness at comparatively low levels.

Extensive laboratory evaluations have shown Sorbistat-K to be usually effective at approximately one fourth the level of propionate and at about one third the level of benzoate. In addition, at practical use levels Sorbistat-K does not impart any off-flavor to the food product.

Specifically, Sorbistat-K has proven effective in chocolate cake, pound cake, yellow cake, white cake, cheese cake, angel food cake, fruit cake and marble cake. It is also of value in many pies, filled sweet goods and cookies. The exact level of use will vary with the type of food, degree of protection needed and the amount of contamination present.

Sorbistat-K, because of its excellent water-soluble properties, can be added directly to batters in the dry form or as a water solution of potassium sorbate. If you would like further information on glucono-delta-lactone, fumaric acid, cream of tartar or Sorbistat-K, write **CHAS. PFIZER & CO., INC., Chemical Sales Division, 630 Flushing Avenue, Brooklyn 6, New York. Branch Offices: Clifton, N. J.; Chicago, Ill.; San Francisco, Calif.; Vernon, Calif.; Atlanta, Ga.; Dallas, Texas.**



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dietary observations. A wider choice of those foodstuffs shown by experience and by experiment to be useful components of the daily ration is the best possible protection against nutritional disease. Similar conclusions have been reported to the American Heart Association and the Society for the Study of Arteriosclerosis (102)."[b]

Evidence from animal studies supports the view that a moderate intake of unsaturated fatty acids, including special consideration of linoleic acid, is more favorable to growth and metabolic adjustment than a diet lacking in these fatty acids. Evidence also supports the concept that the ratio of unsaturated to saturated fatty acids is significant with respect to growth and serum cholesterol concentrations in experimental aminals and men. Linoleic acid is of major importance in a practical sense because of its common occurrence in a great number of edible fats and oils, and because of its ready conversion to arachidonic acid and other fatty acids required in cellular functions. There has been much speculation in regard to the limited capacity of animals and man to utilize the high melting fatty acids (straight chain, trans- and delta-isomeric forms) but the evidence thus far available is not convincing that these acids now impose a practical hazard to human health for normal individuals on a representative mixed diet. Under extreme conditions, such as one can devise for experimental animals, or in the medical care of individual patients, the situation is obviously different.

There is relatively good agreement among leading medical scientists that coronary heart disease, cerebral strokes, and atherosclerosis are not established as being solely dependent on dietary practices nor upon fat intake as a single feature of the diet. Nevertheless, there is enough evidence that dietary practices may be an important part of the total picture, to make the need for intensive research clearly urgent. Even if other factors may play a dominant causative role, it is only good judgment to find what dietary practices are likely to induce the best degree of defense. There is good agreement that the hereditary tendency or familial trend, is a factor of major importance. When the risk in this direction is known to be high, stringent measures of all kinds are in like degree justified. Hence, it is important to know what nutritional practices are most likely to offer any possible advantage to individuals in either a preventive or therapeutic sense of conserving public health.

In so far as dietary measures are now indicated as having a possible influence on the health trend for this group of diseases, excessive consumption of calories appears to be of greatest importance for continued investigation. Gorging at a single meal also is regarded as an added risk, in contrast to eating smaller, well balanced meals more regularly. One should also note that deficiencies or imbalances of vitamin B_6, choline, amino acids (protein), calcium, magnesium, sodium and potassium, can affect the course of atherosclerotic changes in experimental animals. Extremely little information is available regarding the influence of these nutrients in human experience.

A major aspect of risks to health that are now associated vaguely with disturbances in fat metabolism is with reference to regulating the tendency for blood clots to form or to be redissolved. This area of research is highly complex and includes consideration of very sensitive balances between proteins, fats, enzymes, minerals and perhaps many other ingredients of the circulating blood-stream and on blood cell or blood-vessel surfaces.

Fortunately, a few research pathologists, for example Dr. W. S. Hartroft and his associates at Washington University and others are giving special attention to those aspects of the problem.

Irrespective of what the dominant factors may be in the causation of the diseases associated vaguely with abnormal fat metabolism, preliminary indications point toward an important role for nutrition in protecting the body in some degree against the hazards of both abnormal clot formation and atherosclerosis. In this sense, nutrition scientists working in cooperation with the food industry have a good opportunity to develop new information of very great potential value in protecting public health.

In addition to the bulletin published by the National Research Council, I believe everyone seriously interested in the subject of fat metabolism and its relationship to health should be familiar with the paper published last year by Edward A. Lew, statistician of the Metropolitan Life Insurance Company, January 15, 1957 "Some Implications of Mortality Statistics Relating to Coronary Artery Disease." In this paper Dr. Lew gives a critical appraisal of recent trends in the incidence of coronary heart disease, with an emphasis upon the gradual nature of changes that have taken place. Especially significant is Dr. Lew's explanation of the importance of changes in classifying causes of death (adopted in 1949) which accounted for approximately 40% of the apparent increase in the death rate from coronary heart disease and the further fact that approximately 30% of the apparent increase from 1940 to 1955 is due to the increased proportion of persons that now survive into the upper-age brackets. He also cites the apparent importance of genetics, heavy cigarette smoking, and overweight.

A BALANCED PERSPECTIVE IS NECESSARY

An important reason for keeping a balanced perspective in the present situation arises from the fact that the most cogent information is very incomplete and premature conclusions about the role of fat in relation to health tend to encourage extreme dietary measures that border on faddism and hence lead to greater risks to health than would be accomplished by following the types of diets that are now recognized as good or excellent. The faddists and hyperenthusiasts are like the gadfly's definition of a consultant—a man who knows less about your business than you do, but who charges you more for his

[b] The Role of Dietary Fat in Human Health. N.R.C. Publication No. 575, 1958, $1.00.

advice than you could possibly make if you ran it the way you should instead of the way he tells you to.

One cannot in fairness differentiate in a blanket nutritional sense between fats and oils of plant or animal origin; nor in blanket fashion can one classify all unsaturated oils as beneficial compared to moderately saturated fats. For example coconut oil which is saturated, and linseed oil and tung oil which are highly unsaturated are among those that exert a strong trend toward high serum concentrations of cholesterol. The effect of oleic acid which is one of the dominant fatty acids occurring both in animal fats and in plant oils can be favorable or unfavorable in its effect upon serum cholesterol concentration, depending upon other variables in the diet. Again, the effect on serum cholesterol concentration induced by common edible fats such as lard, cottonseed oil and corn oil will vary upward or downward depending upon the total caloric intake derived from fats.

In the over-all picture we are still justified in keeping a primary emphasis upon working toward a goal of furnishing to the public, foods that are readily accepted, that promote a voluntary selection of well balanced diets, and that permit a wide range in selections to meet personal preferences and different economic requirements.

In the immediate future, the most urgent need is to identify by research the relative and quantitative effects of different nutrients upon the human diseases closely associated with disturbances in fat metabolism. Until further evidence is available from studies of actual heart attacks and cerebral hemorrhages, changes in serum cholesterol, blood clotting tendencies and changes in blood pressure seem to furnish the best clues in guiding these investigations.

An alert food industry, meanwhile is exploring practical measures for conserving the linoleic acid content of foodstuffs, and balancing this nutrient with all the nutrients required for safeguarding public health. Recent spectacular advances in methods of fat analysis, and in the use of radiocarbon to trace the metabolism of fats, have opened a new day for research scientists to obtain the much-needed information.

IN CONCLUSION

Fats of many kinds and great complexity are characteristic of all living organisms, and the human body, like others is capable of adjusting a great variety and wide quantitative range of lipid materials into its normal functions. As with other nutrients, the margins of relative safety and optimum intakes over a long-time interval are not well established. The advantages in flavor, satiety, consistency, appearance, economy, convenience, caloric efficiency, and practical sources of vitamins and essential fatty acids can be achieved readily within wide ranges of intake from both plant and animal foods. The latter are especially important however as sources of good quality proteins, water-soluble vitamins, minerals and flavor.

Research is needed to establish the significance of a great number of variables that affect fat tolerances and advantages, e.g. total caloric balance, hormone balance, ratios of fatty acids ingested, clotting control, exercise, genetic pattern, smoking habits, chemical and infection stresses, quality and quantity of protein eaten, and the intake of several vitamins (at least B_6, C and choline) and minerals (especially Mg, Ca, K and Na).

Factors Affecting Water-Vapor Transfer Through Food Packaging Films[a,b]

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(Manuscript received May 31, 1958)

IT IS GENERALLY RECOGNIZED that packaging has a profound effect on the ultimate quality of food products reaching the consumer. For this reason the selection of proper packaging materials and methods has become one of the major problems of the Food Technologist.

It is present practice to select packaging materials on the basis of storage studies using the food product to be packaged. Laboratory tests on packaging materials are used as a guide in selection *(10, 20)*, but prediction of expected shelf life on the basis of such tests is as yet not possible *(17, 18)*. One of the reasons for this is the need for better correlation between performance of packaging materials under laboratory conditions and under conditions of final use.

In the field of flexible packaging, one of the most important properties is the water-vapor permeability *(5)*. Accurate tests for the measurement of this property exist, and water-vapor permeabilities of most packaging materials have been reported *(16, 18, 22)*. Most of these tests, however, have been conducted only at one particular condition of temperature and humidity. The application of such data to other conditions is not always possible.

In view of the above considerations the authors have undertaken a study with the following objectives:

1) To determine the water-vapor permeability of several commonly used packaging films at various conditions of temperature and humidity.

2) To investigate the applicability of theoretical equations for prediction of water-vapor permeability at a given temperature and humidity conditions on the basis of data obtained for other conditions.

It is hoped that the results presented in this paper will facilitate the rational selection of packaging materials for use with foods to be stored at various conditions of temperature and humidity.

EXPERIMENTAL

Materials. The food packaging materials used in this study were obtained from several manufacturers, and were stored before being tested in an air conditioned room at 25° C. and 50% relative humidity. The materials studied included:

1. Two lots of plain cellophane—(lot A 1.25 mil average thickness; lot B 1.3 mil average thickness)
2. Polyethylene coated cellophane—Average thickness: 1.50 mil
3. Saran-coated cellophane—Average thickness: 1.10 mil
4. Saran—Average thickness: 1.25 mil
5. Polyethylene—Average thickness: 3.20 mil
6. Pliofilm—Average thickness: 1.80 mil
7. Polystyrene—Average thickness: 3.15 mil

Methods. All tests were conducted according to the standard TAPPI method *(23)* with the following modifications:

1. The temperature and humidities of the tests included conditions other than those provided by the standard test. A complete list of conditions is given in Table 1. The different humidities were obtained by placing the permeability cups in desiccators in which the humidity was kept constant by saturated salt solutions, as suggested by Wink *(25)*. These solutions are also listed in Table 1. The different temperatures were selected because of the availability of constant temperature rooms maintained at those temperatures. In each case checks of the temperatures and humidities were made using American Instrument Company Electric Hygrometer Equipment *(2)*.

TABLE 1

Conditions of water-vapor permeability tests

Temperature °C.	Relative humidity %	Vapor pressure mm. Hg	Solution used to obtain the desired humidity
2	95	5.05	Water
20	95	16.7	Water
30	95	30.4	Water
37.7	11	5.5	LiCl
37.7	20	10.0	$KC_2H_3O_2$
37.7	32	15.6	$MgCl_2 \cdot 6H_2O$
37.7	43.5	21.3	K_2CO_3
37.7	46	22.5	KNO_2
37.7	53.5	26.4	NaBr
37.7	62	30.3	$NaNO_2$
37.7	75	36.9	NaCl
37.7	86	42.1	K_2CrO_4
37.7	91	44.7	$NH_4H_2PO_4$
37.7	95	46.6	Water
57	95	124	Water

2. For tests conducted at 57° C. the wax for sealing the permeability cups was modified as follows: four parts of microcrystalline wax to one part of paraffin.

Theoretical considerations. Water-vapor permeability values are reported in the literature in two types of units. The first of these, usually called moisture-vapor-transfer-rate (MVTR) is expressed in terms of weight of moisture passing through a unit area of material per unit time, at specified conditions of temperature and humidity, and for a given thickness of the test material. Because of these restrictions the unit does not allow the extrapolation to other conditions of temperature, humidity and film thickness.

A second unit, frequently designated as the permeability constant, has the dimension of weight of moisture per unit area per unit time per unit thickness and per unit vapor pressure differential. Only temperatures need be specified in this unit.

Using the permeability constant it is possible to calculate, for a given temperature, the transfer rates for films of different thickness and for various humidities. Its use, however, involves several implicit assumptions, which are discussed on the following page.

[a] Contribution No. 359 from the Department of Food Technology, Massachusetts Institute of Technology.

[b] Presented at the 18th Annual Meeting, Institute of Food Technologists, Chicago, May 28, 1958.

Consider a film placed between an area of high water-vapor-pressure and an area of low water-vapor-pressure. At any time, the concentration of water on the high pressure side of film will be higher than the corresponding concentration on the low pressure side. A concentration gradient *through the film* will result, and diffusion will take place in the direction of decreasing concentration.

Fick's law of diffusion states that the flux of the diffusing water vapor will be proportional to the concentration gradient (eq. 1) *(3)*.

$$F = -D \frac{\delta c}{\delta x} \qquad (1)$$

This partial differential expression can be changed to the exact differential form (eq. 2), provided the following assumptions are made:

1. The diffusion is in a steady state.
2. There is a linear gradient through the film.
3. The diffusion takes place in one direction only.

$$\frac{dw}{d\Theta} = KA \frac{C_2 - C_1}{\Delta X} \qquad (2)$$

where: w — amount of water vapor diffusing through the film
Θ — time
K — a constant
C_2 — water concentration at high pressure side of film
C_1 — water concentration at low pressure side of film
A — area of film
ΔX — thickness of film

The assumption that the linear gradient does not change with time, allows the integration, which yields equation 3.

$$\Delta W = KA \frac{(C_2 - C_1)\,\Delta\Theta}{\Delta X} \qquad (3)$$

Since it is usually impractical to determine concentrations directly, the driving force is expressed in terms of partial pressure differential, rather than in terms of the concentration gradient. This necessitates the assumption that Henry's Law is applicable (eq. 4).

$$C = Hp \qquad (4)$$

where: C — concentration of water at film surface
p — partial pressure of water
H — a constant

On the basis of equations 3 and 4 it is possible to write equation 5,

$$\Delta W = K^1 A \frac{(P_2 - P_1)\,\Delta\Theta}{\Delta X} \qquad (5)$$

A rearrangement of equation 5 gives the definition of the permeability constant (eq. 6).

$$K^1 = \frac{(\Delta W)\,(\Delta X)}{(A)\,(\Delta\Theta)}\,(P_2 - P_1) \equiv P.C. \qquad (6)$$

where: P. C. —permeability constant.

The temperature dependence of the permeability can also be expressed analytically. The most frequently used expression is shown in equation 7 *(11)*,

$$P.C. = P_o e^{-E/RT} \qquad (7)$$

where: P_o — a temperature independent constant
E — activation energy of permeability
R — gas constant
T — absolute temperature

The practical significance of these relations is apparent from the following considerations. If these relations hold, it is only necessary to determine the water-vapor-permeability of a given material, at two different conditions of temperature and humidity. The transfer rate at other conditions can then be calculated mathematically, or found graphically. This last method is based on the fact that if the equations listed above are applicable, plotting of ln P. C. against 1/T should result in a straight line. A straight line with a slope independent of temperature can also be obtained by plotting P. C. against ln p *(19)*.

When results obtained at different humidities, but at constant temperature, are compared, it is frequently advantageous to plot the transfer rate against the partial pressure differential *(13)*. This plot should also result in a straight line passing through the origin.

Another consideration, important in practice, arises from the fact that there are several different methods for the determination of water-vapor permeability. If the ideal relations described above are valid, results obtained by different methods can be easily correlated. If, however, relations between transfer rate and test conditions are unknown, it is possible to compare results only when they are obtained by the same method and under the same conditions.

Unfortunately, in many cases considerable deviation from the ideal relations has been observed *(1, 9)* which may be due to the fact that:

1. Henry's law does not apply, and the materials have curved adsorption isotherms.
2. In many materials this assumption of a linear gradient is not justified.
3. Temperature may affect materials in a way resulting in deviations from equation 7.
4. In some materials it is difficult to attain steady state conditions.

These deviations have been recognized and some attempts have been made to derive more general theoretical expressions. Jost *(12)* and Barrer *(3)* have derived solutions for unsteady state diffusion and for non-linear gradients, but their application to food packaging materials has been limited.

Recently, Hilton *(11)* presented a derivation in which the diffusion is treated as composed of three separate stages. This author suggested that a plot of vapor pressure against the log of permeability would yield a straight line in the region above 30% relative humidity. As will be shown later, however, our experimental data fail to support this assumed relation.

In order to test the applicability of the various theoretical equations the results are expressed in two units, which are defined in Equations 8 and 9. In each case the results are corrected to unit thickness, on the basis of the average thickness of each sample, which was determined from several gauge measurements. It is considered that this correction is justified because the thickness of the different samples in each lot varied only 10–15%, and in this range the assumption of a linear relation between the reciprocal of thickness and the transfer rate would not lead to serious error.

$$Q \equiv \frac{\Delta W\,\Delta X}{\Delta\Theta\ A} \text{ in } \frac{\text{g.} - \text{mils}}{24 \text{ hrs.} - 100 \text{ in.}^2} \qquad (8)$$

$$P.C. \equiv \frac{\Delta W\,\Delta X}{\Delta\Theta\ A\,(P_2 - P_1)} \text{ in } \frac{\text{g.} - \text{mils}}{24 \text{ hrs.} - 100 \text{ in.}^2 - \text{cm. Hg}} \qquad (9)$$

RESULTS AND DISCUSSION

I. Studies at various humidities and at 37.7° C.

The results obtained at various relative humidities at 37.7° C. are shown in Figures 1 through 6.

Figures 1 through 4 represent plots of the transfer rate (Q) against partial pressure of water, and the corresponding relative humidities. If the ideal relations between vapor pressure and transfer rate were followed, the plots should have resulted in straight lines, passing through the origin. The results obtained with saran film and mylar (Figure 1) fit this theoretical relation well. In the case of polyethylene, and polystyrene (Figure 2) some deviations are apparent. The curves have a sigmoidal shape and appear to follow exponential, rather than linear rela-

tions *(6)*. It appears likely that these deviations are due to the non-linear nature of the water adsorption isotherms of these materials *(4, 8, 15, 21)*. In spite of these deviations a straight line representation appears to be sufficiently accurate for practical purposes.

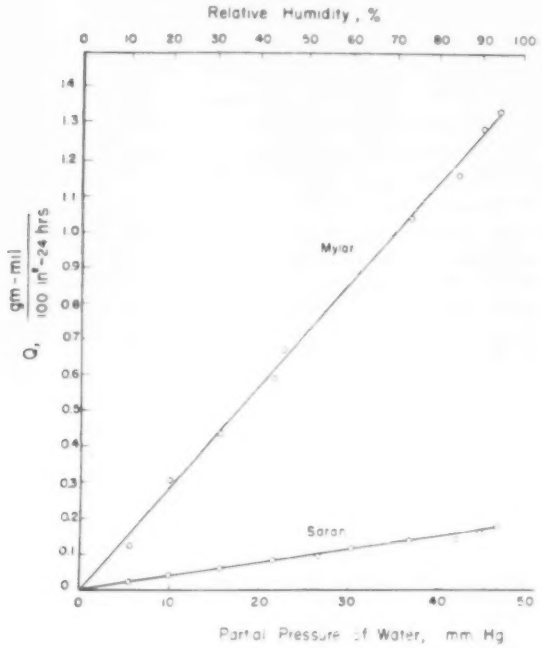

Figure 1. Water vapor transfer rate of Mylar and Saran film, at 37.7° C. as a function of partial pressure of water.

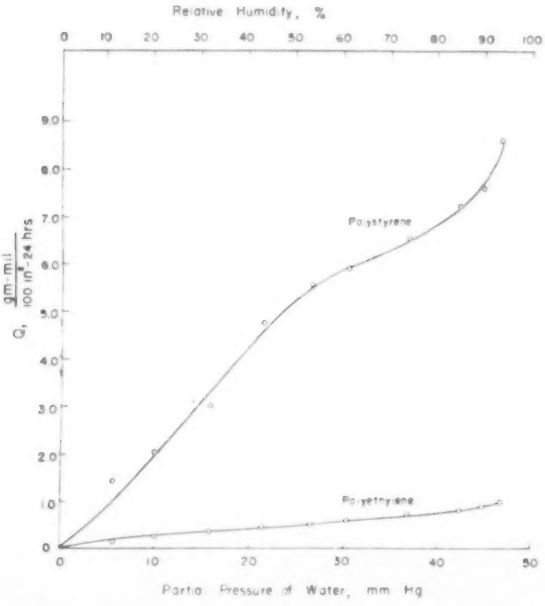

Figure 2. Water vapor transfer rate of Polyethylene and Polystyrene films, at 37.7° C. as a function of partial pressure of water.

In the case of the packaging films based on cellulose, however, the deviations are very considerable, and an attempt at linear correlation would result in errors that have practical significance. The curves for plain cellophanes (Figure 3) show an exponential relationship very similar to the water-vapor-cellulose adsorption isotherm *(1, 15, 24)*.

In the case of coated cellophanes the curves have a more complicated character (Figure 4). At high humidities the transfer rates increase sharply and the curves resemble those obtained with plain cellophanes. At lower humidities the curves are similar to those obtained with the films of which the respective coatings are made (polyethylene and saran). The humidity range at which the apparent change in the mechanism of transfer occurs is 80–90%. It is interesting to note that very similar results were obtained by other workers *(10)* on conventional moisture-proof cellophanes in which the coating composition is based on nitrocellulose.

Because of the deviations from linear relations in several of the materials, use was made of the suggestion by Hilton *(11)* that the log of transfer rate against relative humidity results in a straight line for values of relative humidity over 30%. Such a plot is presented in Figure 5. It is evident from this figure that the suggested relationship appears to apply fairly well to polyethylene and to plain cellophanes. None of the remaining five materials, how-

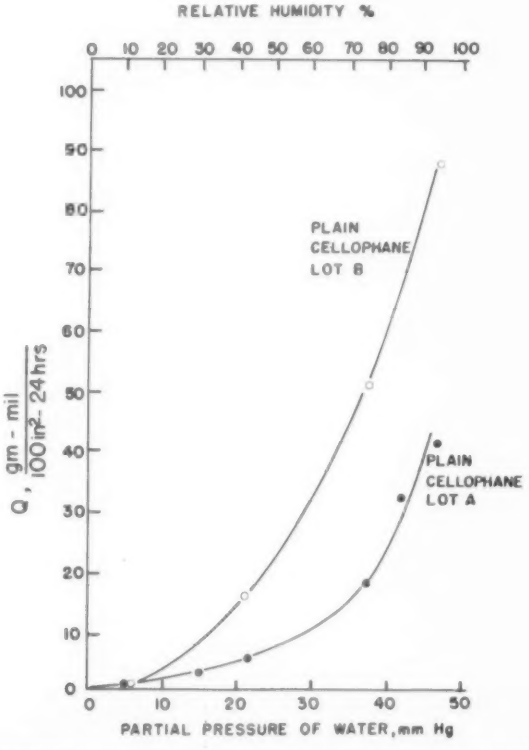

Figure 3. Water vapor transfer rate of two lots of plain Cellophane, at 37.7° C. as a function of partial pressure of water.

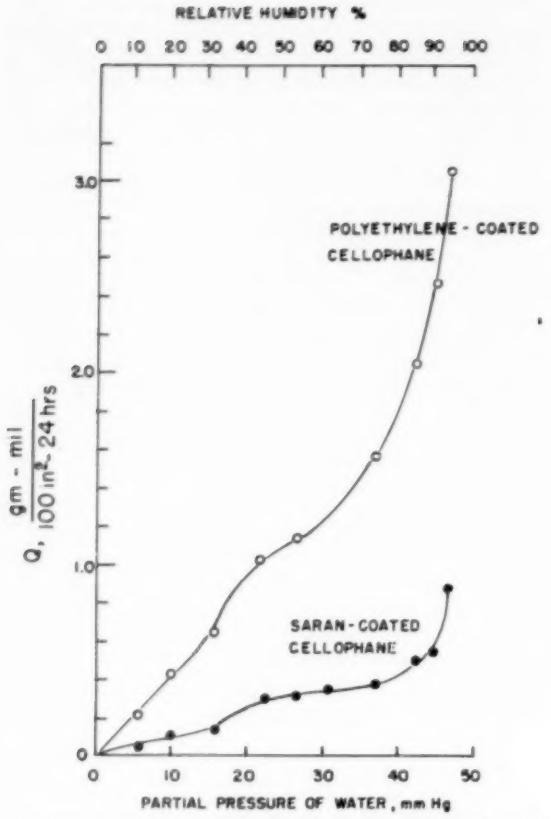
RELATIVE HUMIDITY %
0 10 20 30 40 50 60 70 80 90 100
3.0
2.0
1.0
0
POLYETHYLENE - COATED CELLOPHANE
SARAN-COATED CELLOPHANE
Q, gm - mil / 100 in² - 24 hrs
0 10 20 30 40 50
PARTIAL PRESSURE OF WATER, mm Hg

Figure 4. Water vapor transfer rate of two types of coated Cellophane, at 37.7° C. as a function of partial pressure of water.

ever, showed a linear correlation. It appears, therefore, that the suggested relationship has only limited application.

In order to show the relative magnitudes of permeabilities of the various films, the permeability constant (P. C.) is plotted against partial pressure of water in Figure 6. To allow comparison between materials varying in permeability by a factor of over a hundred, use is made of a logarithmic ordinate.

II. Studies at 95% relative humidity at various temperatures

Results obtained at 95% relative humidity and at temperatures ranging from 2° C. to 57° C. are presented graphically in Figures 7 through 9.

The transfer rates of the various materials are plotted against 1/T in Figures 7 and 8. In Figure 9 the permeability constant (P. C.) is plotted against 1/T. For ideal conditions these plots should result in straight lines with a negative slope. It is evident from the results, that this relation is followed in general, but that there are several important deviations. These deviations are as follows:

1. At the lowest test temperature (2° C.) four of the materials show transfer rates that are higher than expected by theoretical extrapolation. These materials are saran, polyethylene, mylar, and saran-coated cellophane.

2. At the same temperature the polyethylene-coated cellophane showed a transfer rate that was lower than expected.

3. The permeability constant of polystyrene actually increased with decreasing temperature, indicating a behavior opposite to that observed with other types of plastics. The anomalous behavior of polystyrene with respect to temperature coefficient of permeability has been observed by other workers *(7)*.

4. The permeability constant for plain cellophane is higher at 37.7° C. than at 57° C.

It appears likely that these deviations are partially due to direct temperature effects on the packaging materials, and also to the temperature effect on absorption and solubility of water in the plastic films. Recent work on plasticized and unplasticized vinyl copolymers *(14)* lends support to this tentative conclusion.

SUMMARY AND CONCLUSIONS

The need for a knowledge of the relations between permeability at the storage conditions commonly found in practice and laboratory conditions has been

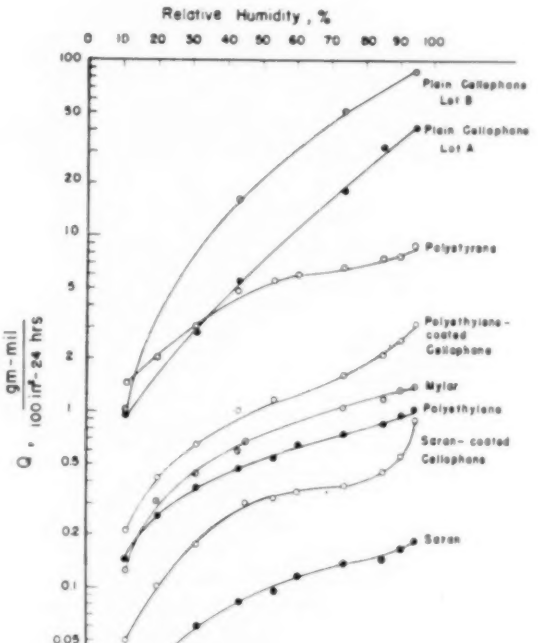

Figure 5. Water vapor transfer rate of several packaging films, at 37.7° C. as a function of partial pressure of water.

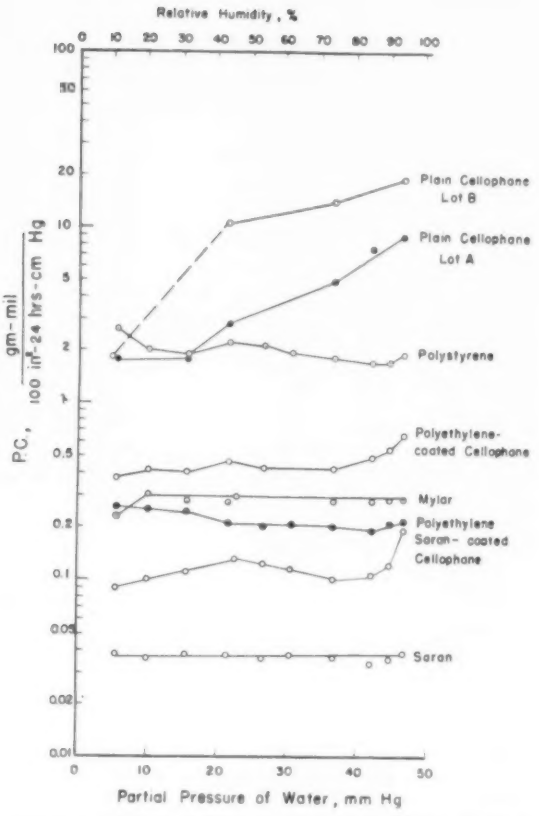

Figure 6. Comparison of water vapor permeability constants of several packaging films, at 37.7° C., as a function of partial pressure of water.

pointed out. It is current practice to assume a linear relation between the transfer rate and water-vapor pressure differential and between the reciprocal of absolute temperature and the permeability constant. These relations are based on several simplifying assumptions concerning the mechanism of water-vapor transfer.

Results of water-vapor permeability measurements on several commonly used packaging materials at various conditions of temperature and humidity have been presented. The results appear to support the following general conclusions:

1. The assumption of a linear relation between water-vapor transfer rate and partial pressure differential appears to be justified for hydrophobic plastics including saran, mylar, polystyrene, and polyethylene. The deviations occurring in the two last mentioned materials are slight and could be ignored in practice.

2. In materials based on cellulose, deviations from linearity are of sufficient magnitude to preclude the use of ideal relations in practical calculations. For such materials it is necessary to obtain data at conditions of use. No simple alternate methods of calculation that apply to all of such materials appears to be available.

3. The theoretical relations for dependence of permeability on temperature appear to apply in the range of temperatures between 20 and 57° C. and probably also at somewhat lower temperatures. Permeability measurements at two temperatures may be sufficient to define this relation in the temperature range mentioned above.

4. At temperatures approaching the freezing point of water, deviations from ideal relations become considerable. It appears advisable therefore, to conduct tests at such temperatures when the intended use of the packaging materials includes refrigerated storage.

5. It appears justified to conclude that a need still exists for basic studies into the mechanism of water-vapor transfer at low temperatures, and for further investigation of the relations between composition and permeability, especially for non-homogeneous (coated and laminated) materials.

Acknowledgments

The authors are grateful to the American Viscose Company for a grant-in-aid which enabled this study to be undertaken, and especially to Dr. R. T. K. Cornwell for his interest in the research.

Thanks are also due to Mr. H. Martin for technical assistance.

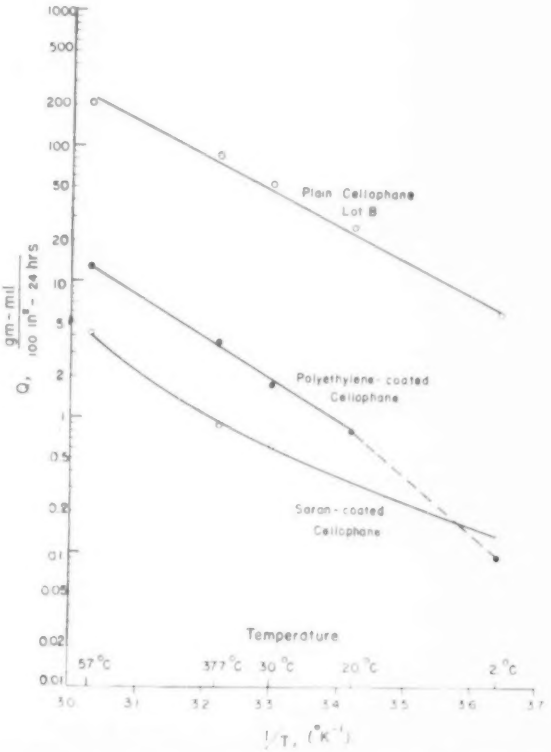

Figure 7. Water vapor transfer rate of three types of Cellophane, at 95% relative humidity, as a function of the reciprocal of absolute temperature. (The test temperatures are indicated on the abscissa.)

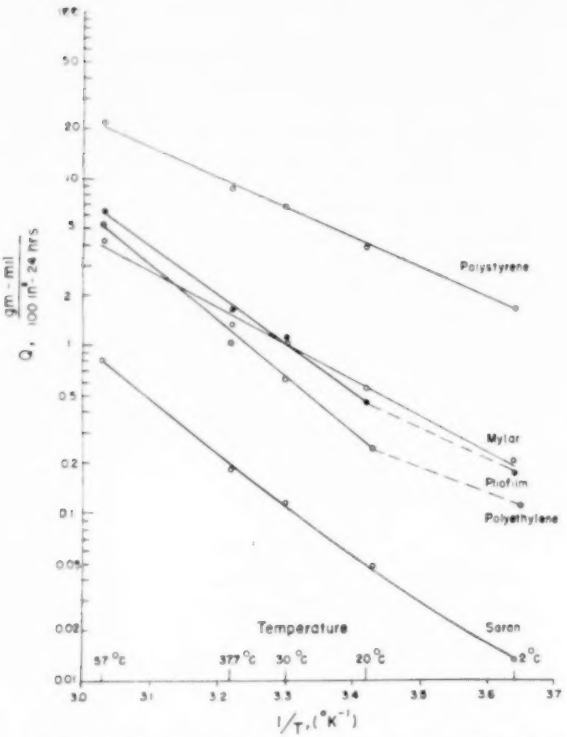

Figure 8. Water vapor transfer rate of several packaging films, at 95% relative humidity, as a function of the reciprocal of absolute temperature. (Test temperatures are indicated on the abscissa.)

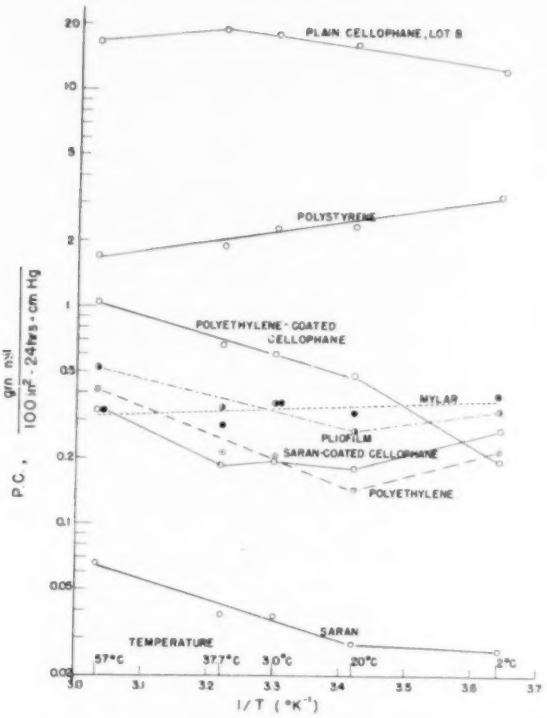

Figure 9. Comparison of water vapor permeability constants of several packaging materials, at 95% relative humidity, as a function of the reciprocal of absolute temperature. (The test temperatures are indicated on the abscissa.)

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Gamma Ray Pasteurization of Whole Eviscerated Chickens[a]

(Manuscript received May 31, 1958)

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ALTHOUGH STERILIZATION of meat can be accomplished by the application of ionizing radiations, a number of difficulties are encountered. Probably the most important are the chemical reactions induced in the food by the radiation dosage required for sterilization. It is generally concluded that a dosage level above 3 megarep is needed to obtain sterility in most food products *(7, 11)*. In sterilizing fresh meats with gamma rays, Brownell *(3)* reported definite undesirable flavor changes. Hannan *(7)* noted that off-odors and off-flavors induced by high level irradiation of various meats varied in their intensity depending upon the type of meat being treated.

Another important difficulty is that enzymes are not inactivated by the usual sterilizing dosage. Dunn *(6)* treated comminuted chicken livers with radiation doses as high as 5 megarep without inactivating all of the enzymes. Those remaining active continue to catalyze degradative changes in food constituents. Thus, at a rate depending upon the temperature and other environmental conditions, we may expect the sterile food to undergo a continuous decrease in organoleptic acceptability during subsequent storage. A preliminary heating of the product prior to the radiation treatment may eliminate the enzyme problem but the food can no longer be considered fresh.

Organoleptic acceptability of the food is probably not reduced when low levels of radiation are applied. Thus, Proctor *(9)* reported that in four out of six separate trials there was no significant difference in flavor between chicken samples treated with 2 megarep and the controls. Because they destroy almost all the bacteria present, these low levels are known as "pasteurizing doses" of irradiation. Refrigerated storage after gamma ray pasteurization should serve to inhibit proliferation of remaining bacteria as well as activity of enzymes. Rather than a true preservation, an extension of fresh shelf life would be obtained.

Therefore, it was desired to investigate the effect of pasteurization doses of gamma rays on the refrigerated storage life of whole eviscerated chickens packaged in plastic bags. Microbiological, physical, and organoleptic examinations were to be used in the evaluation of treatments.

Several workers in the irradiation field have investigated use of pasteurization dosages. Niven *(8)*, in working with meat, showed that the most important group of organisms resulting in surface slime, discoloration and off-odor was the genus *Pseudomonas*. He also demonstrated that when a dosage of 100,000 rep was used there was an appreciable extension of shelf life at 2° C. Proctor *(10)* irradiated ground beef with 1 megarep and stored the samples at 36–40° F. He found there was a 12-week extension of the storage life. However, it was found that 0.3% sodium fumarate and 0.5% monosodium glutamate had to be added in order to obviate the irradiation flavor. Brownell *(5)* inoculated ground beef samples with psychrophilic organisms prior to use of pasteurization doses of irradiation and then stored the samples at 4° C. He found that the growth of microorganisms in the irradiated samples showed a lag period of growth relative to the growth observed in the controls. He also showed that the lag period increased with increasing radiation dosage. However, after this lag period the microorganism count of the irradiated samples increased as a log function of time in a manner similar to that of the controls.

MATERIALS AND METHODS

Raw material. Fresh chickens used in these studies were procured from a local poultry processing plant. To assure uniformity of samples, birds were chosen at random from the processing line with the only stipulation that they weigh between 2 and 2½ pounds after dressing. Hot evisceration was employed in the dressing operation. The birds were then slush-ice cooled for 24 hours, and the average body temperature of the birds was reduced to approximately 34° F. The chickens, with giblets removed, were next placed in polyethylene bags (.0015 in. thickness) using care to physically force as much air out of the package as possible before tying the bag. Packaged poultry was placed in an insulated box with layers of chipped ice distributed around the birds to assure maintenance of the low body temperature. The insulated box and contents were then transported to the Michigan Memorial Phoenix Project, University of Michigan, Ann Arbor, where radiation was accomplished.

Radiation. Two gamma ray sources were used. One source consisted of partially spent fuel elements; the other source contained rods of Cobalt 60. Radiation of the chickens was carried out in a "radiation cave" similar to the one described by Brownell *(4)*. The packaged chickens were prepared for irradiation by placing them in a vertical position in individual, round cardboard containers. Crushed ice was filled into each carton around the bird. Lids were placed on the cartons and the packages were immediately transferred to the radiation cave. The chipped ice served to keep each bird in a vertical position during irradiation and, more important, to maintain the body temperature of the birds at approximately 34° F. Containers holding the chickens were placed in a circle around the radiation source with the center of each chicken exactly 50 cm. from the center of the source. Containers were rotated manually at regular intervals of time to assure that each bird was uniformly irradiated. A ferrous sulfate dosimeter was used, according to Weiss *(13)*, to determine the radiation dose at the center of each bird.

[a] Presented at the Eighteenth Annual Meeting of the Institute of Food Technologists, Chicago, May 27, 1958.

[b] University of Michigan, Department of Bacteriology, Ann Arbor, Michigan.

After the packaged chickens had received their assigned dosage of gamma rays, they were removed from the cartons, replaced in the insulated box and kept under chipped ice. The ice was replenished for the return trip and upon arrival at the University of Illinois they were placed in constant temperature storage boxes.

Controls. A series of unirradiated control samples were obtained by randomly selecting chickens at the time of packaging and labeling them as controls. These birds were then packed in ice along with those to be radiated, carried through the entire procedure, except for radiation, and then placed in storage at the various temperatures with the irradiated birds.

Bacteriological analysis. Total plate counts were used to determine aerobic bacteria. The procedure followed was the standard method of analysis recommended by the American Public Health Association *(1)*. Three sampling techniques were used: (a) outside swab of the skin, (b) tissue sample, and (c) cavity swab.

To obtain the outside swab of the skin the procedure of Ayres *(2)* was followed. After the polyethylene bag had been removed, a sterile cardboard ring was placed on the breast of the chicken. This ring had an inside area of 12 square centimeters. A sterile swab, wetted in sterile saline solution, was then rolled over the surface of the skin contained in the inner-diameter of the ring. The lower portion of this swab, with the cotton intact, was then aseptically transferred to 99 ml. of sterile saline solution. Contents of the dilution bottles were thoroughly mixed by shaking and dilutions were plated.

The tissue sample was obtained by aseptically removing the skin from a large area of the breast of the chicken. An 11-gram sample of tissue was removed from the center of this large skinned area. The tissue sample was placed in a sterile Osterizer with 99 ml. of sterile saline and the sample was disintegrated for 3 minutes. Appropriate dilutions were plated.

The cavity swab was obtained by cutting open one body cavity wall and applying the same type of ring used for the outside swab sample. This area was then swabbed and the same procedure followed as with the outside swab.

All of the plate cultures were incubated at 30° C. and the colonies were counted after 48 hours.

Qualitative determination of slime. Ayres *(2)* has shown that spoilage of chicken held at refrigerated temperatures is accompanied by slime formation. In order to determine rapidly when there was an extensive growth of microorganisms on the surface causing slime, the method of Ziegler *(14)* was used.

Physical examination. A panel of 2 to 3 judges made a physical examination of the chickens for odor and slime immediately after samples for microbiological analyses were taken.

Organoleptic analyses. In preparation for the organoleptic evaluation, the chickens were individually wrapped in aluminum foil and roasted for 1½ hours at 375° F. After cooking, the meat was removed from the bones and skin; the dark and the white meat of each chicken were separated into individual portions. Organoleptic ratings were determined by a taste panel of 10 staff members of the Department. Samples were graded 1 to 9, with 9 being *excellent* and 1 being *extremely poor*. On this scale a grade of 5 was just acceptable. Samples were graded on flavor, color, texture, and off-flavor. All samples in one replicate were given arbitrary identification numbers and judged at each testing time.

To aid the judges in determining a proper grade for each sample, a reference sample was included with those being tested. Reference chickens were obtained by randomly choosing several chickens immediately after the packaging operation. These birds were rapidly frozen in a −40° F. room and stored at −40° F. until needed. By quick-freezing these chickens and holding them at very low storage temperature for only 2 to 3 weeks, it was believed they represented the original quality of the fresh chickens. Thus, in using these chickens as a reference point, any quality changes occurring in the experimental birds could be readily detected by the judges.

RESULTS AND DISCUSSION

This study was carried out in 3 phases. Cobalt 60 and fuel element radiation sources were used in separate studies and then compared in a single experiment. The results obtained are presented accordingly.

Throughout this study there was no general tendency for the swab inside count to be lower or higher than the swab outside counts. Plate counts for the tissue samples were also of the same order of magnitude in each case as the swab outside counts, although they were based on number of colonies per gram. Therefore, unless otherwise specified, any TPC (Total Plate Count) given is taken from the data for swab outside counts and may be considered representative of the general microbiological condition of the chicken.

Ziegler's technique was used as a quick test to determine the microbiological condition of the samples. On all samples that contained a TPC in the order of 10^6 colonies/cm.^{2}, the Ziegler method gave positive slides. Thus, it was found to be a very acceptable method.

Separate studies on the effect of Cobalt 60 and fuel elements. Each study was designed to give the same storage conditions and required not more than 72 chickens. When spoilage became evident, the remaining birds at the specific storage condition were discarded.

In this phase of the study the same procedures were used as described in Materials and Methods. Dosage levels of zero, 1 x 10^5 and 5 x 10^5 rep were employed. After return to the University of Illinois, the birds were stored at 0°, 34°, 40°, and 50° F. (58° F. was used instead of 50° F. for the fuel element study). One chicken at each radiation level was removed from its respective storage temperature and examined after various storage times. In addition to the time the birds were held at the specified storage temperatures, they had all been held covered with ice during the 4-day trip to and from the University of Michigan for irradiation.

Storage after Cobalt 60 radiation. The acceptable storage life of the chickens was found to vary with the storage temperature and the radiation dose as shown in Figure 1. As would be expected, both the radiated and unirradiated birds were found to be microbiologically acceptable after 20 days' storage at 0° F. However, radiation combined with 0° F. storage apparently increased the activity of oxidative processes which cause fat to become rancid. Figure 1 shows that after the birds had been given a radiation dose of 5 x 10^5 rep and stored at 0° F. for 11 days a definite rancid odor was noted during the physical examination. This odor was especially distinguishable during cooking. No rancidity was observed for the birds that had been subjected to zero or 1 x 10^5 rep and stored at 0° F.

When the chickens were stored at 34° F. (Figure 1), it was found that the unirradiated birds were spoiled after 11 days. The surface TPC (Total Plate Count) on these spoiled birds was at least 10^6 colonies/cm.^{2} The birds radiated with Cobalt 60 at a

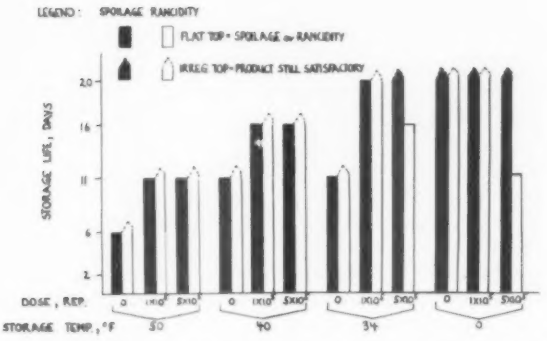

Figure 1. Effect of Cobalt 60 irradiation on development of microbiological spoilage and rancidity in whole eviscerated chickens stored at several temperatures.

level of 1 x 10^5 rep had a surface TPC of 3.4 x 10^2 after 11 days at 34° F. The 5 x 10^5 rep dosage resulted in less than 2.5 x 10^2 colonies/cm.^{2} for the same period. The birds radiated with 1 x 10^5 rep were spoiled at 20 days. However, the chickens given a dose of 5 x 10^5 rep and stored at 34° F. were not considered microbiologically spoiled after 20 days' storage. The TPC of these latter birds was in the order of 10^4 colonies/cm.^{2} after 20 days at 34° F. These examinations indicate that the 34° F. storage life of chickens could be extended at least 5 days if 1 x 10^5 rep were used and over 9 days if 5 x 10^5 rep were used. Rancidity was noted once again in birds that had received the higher dose of gamma rays. This rancid odor was definitely present after 16 days' storage at 34° F. (Figure 1), which represented a "time to rancidity" extension of 5 days in comparison with birds stored at 0° F. Therefore, the lower storage temperature appears to have increased the rate of rancidity development when 5 x 10^5 rep were used.

Cobalt 60 irradiated chickens that were stored at 40° F. followed much the same pattern as those stored at 34° F. Figure 1 shows that with the increase in storage temperature there was a decrease in the microbiological storage life for the irradiated birds. Although it is not evident from examination of Figure 1, the unirradiated birds stored for 11 days at 40° F. had a larger TPC than the unirradiated birds stored for 11 days at 34° F. (10^8 vs. 10^6 colonies/cm.^{2}). This agrees with the data of Ayres *(2)* which showed the organisms present on chickens had a more rapid rate of growth at 40° F. than at 34° F.

There were two other important differences between the birds stored at 40° F. and those stored at 34° F. (Figure 1). First, in 40° F. storage the high dosage birds spoiled at the same time as did the low dosage birds. At 34° F. the higher dose gave an extension of the microbiological storage life. This may indicate that 40° F. is about the critical temperature for the growth of the surviving organisms, but this would have to be established by additional studies. The second difference, observed between the 40° F. storage and the lower storage temperatures, was the lack of rancidity development at the high radiation dose in the former storage condition. These data strengthen the case for the combination of radiation and low refrigerated storage temperature as factors contributing to the development of rancidity. Hannan *(7)*, working with irradiated butterfat, found an increase in peroxide formation as the refrigerated temperature was lowered.

As shown in Figure 1, the unirradiated birds stored at 50° F. spoiled sooner than did the radiated birds. The storage time for all samples at 50° F. was shorter than that for corresponding samples at lower storage temperatures. It should also be noted that at 50° F. storage the high dose birds spoiled as quickly as the low dose birds and no rancidity was detected at any level of irradiation. This was in agreement with the results found at 40° F. storage for similarly treated birds.

Storage after fuel element radiation. Figure 2 indicates that fuel elements gave results at 0° F. storage similar to those found with Cobalt 60. Rancidity was once again pronounced after 11 days storage when 5 x 10^5 rep were used. The surface TPC showed no tendency to increase at any dosage level when this storage temperature was used. The birds stored at 34° F. (Figure 2) gave results for development of microbiological spoilage and rancidity that closely paralleled the findings with Cobalt 60.

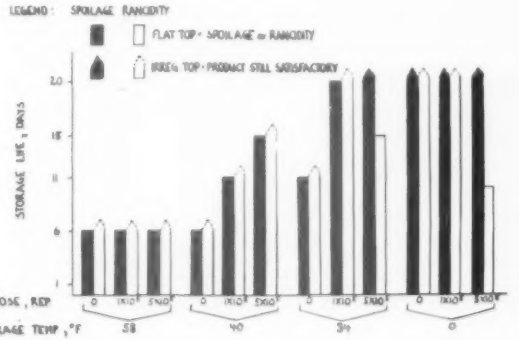

Figure 2. Effect of fuel element irradiation on development of microbiological spoilage and rancidity in whole eviscerated chickens stored at several temperatures.

Figure 2 shows the data for chicken irradiated with fuel elements and stored at 40° F. Birds receiving no irradiation showed microbiological spoilage after 6 days while spoilage occurred at 11 days with 1 x 10^5 rep and at 15 days with 5 x 10^5 rep. Storage times for retaining acceptable products were less for the zero and 1 x 10^5 rep than when Cobalt 60 was used at the same dose level. The original plate counts for the 2 studies were in the same order of magnitude. One explanation that might be suggested for this difference in acceptable storage time is that the initial bacterial population may have varied as to the type present. Since classification of organisms present was not attempted in this study, this theory is merely a suggestion. The extension of the microbiological storage life of 1 x 10^5 rep birds using Cobalt 60 might

also be due to a difference in the effectiveness of the 2 sources. This was investigated and will be reported on in the next section.

The chickens, of all radiation doses, stored at 58° F. (Figure 2) showed spoilage and high bacterial counts after 6 days' storage. Evidently, in this temperature range a dose of 5×10^5 rep was not sufficient to extend the shelf life of the birds. These results magnify the importance of utilizing a storage temperature of 34–40° F. in order that the benefits of low-dose irradiation may be realized.

Organoleptic evaluation. Data presented in the organoleptic tables are the average values as determined by the testers on a blindfold basis. Organoleptic values were at approximately the same level for both the dark and white meat throughout the testing period. This relationship existed even when the scores decreased due to long storage periods.

When Cobalt 60 was used as the radiation source, the organoleptic scores for the dark meat and white meat (Table 1) were at about the same level for both the unirradiated and radiated samples after 2 days' storage. Table 1 also shows that the panel apparently could not differentiate the radiated from the unirradiated samples on any of the factors for which the chickens were graded. This indicates that irradiation flavors were not perceptible to the panel at either the 1×10^5 rep dose or the 5×10^5 rep dose radiation levels.

An examination of Table 2 will indicate that when fuel elements were used as the radiation source no deleterious effects on organoleptic values of the dark meat or the white meat occurred. Again radiation dosage levels were not of sufficient magnitude to cause any radical changes.

Comparison of Cobalt 60 and fuel elements. Fresh whole eviscerated chickens were packaged in polyethylene bags and radiated as described in Materials and Methods. Two irradiation sources, Cobalt 60 and fuel elements, were used to give pasteurization doses of 100,000 rep. One set of birds without irradiation was used as control. After irradiation the chickens were placed at 34° and 40° F. storage. Samples were removed after 2 and 7 days' storage for examination.

Three replications (24 birds in each) were made for each set of conditions and the data were statistically analyzed. A mathematical model was fitted by the method of least squares *(12)*. The numerical values of the fitted constants were determined using the Illiac Computer at the University of Illinois.

Only organoleptic values and logarithms of total plate counts were analyzed statistically. Physical examination and smear slides were used only as a method of determining whether samples were still acceptable for the organoleptic analysis.

1. *Microbiological.* In statistically analyzing the bacteriological data the following independent variables were included in the model: storage period—unstored (2 days) vs. stored (7 days); temperature—34° F. vs. 40° F.; radiation—unirradiated vs. radiated; radiation source—Cobalt 60 vs. fuel elements; storage period x radiation; storage period x source and 3 replications. The results reported here were not considered significant unless the 99% confidence level was exceeded. Table 3 shows mean logarithms for those variables that were significant as determined by the method of least squares.

Storage period was found to significantly affect the number of microorganisms present on each of the three bacteriological samples taken. It is quite evident in Table 3 that the bacteria present at the beginning of storage were able to multiply rapidly in storage. The organisms present were also found to be able to reproduce at a much greater rate at 40° F. than at 34° F. Data also show that the unirradiated birds had a significantly higher population of microorganisms than the radiated, a statistical confirmation of the first two studies.

One of the primary objectives of this study was to determine whether Cobalt 60 and fuel elements had the same effectiveness in destroying bacteria or establishing conditions that would reduce bacterial multiplication. It was found that chickens irradiated with

TABLE 1

Average organoleptic values for whole eviscerated chickens irradiated with Cobalt 60 and stored for 2 days at four temperatures

Irradiation dose (rep)	Temperature	Dark				White			
		Flavor	Color	Texture	Odor	Flavor	Color	Texture	Odor
	°F.								
0	0	8.4	8.1	8.5	8.9	8.5	8.0	8.3	8.9
0	34	8.3	8.7	8.8	8.8	8.8	9.0	8.7	8.9
0	40	8.9	8.7	9.0	8.9	8.7	9.0	8.9	8.9
0	50	8.5	8.7	8.9	8.9	8.9	8.5	8.9	8.9
(average)		8.5	8.5	8.8	8.9	8.7	8.6	8.7	8.9
1×10^5	0	8.5	8.9	8.7	9.0	8.5	8.9	8.7	8.9
1×10^5	34	8.4	8.9	8.7	8.8	8.7	9.0	8.7	8.9
1×10^5	40	8.3	8.7	8.3	8.4	8.7	8.5	8.7	8.9
1×10^5	50	8.7	8.5	8.5	8.9	8.9	8.9	8.9	8.9
(average)		8.5	8.8	8.6	8.8	8.7	8.8	8.8	8.9
5×10^5	0	8.3	8.3	8.4	8.7	8.7	8.4	8.3	8.9
5×10^5	34	8.5	8.6	8.7	9.0	8.6	9.0	8.6	8.9
5×10^5	40	8.0	8.9	8.5	8.9	8.4	9.0	8.9	8.8
5×10^5	50	8.4	8.5	8.7	8.5	8.4	8.9	8.5	8.7
(average)		8.3	8.6	8.6	8.8	8.5	8.8	8.6	8.8

TABLE 2

Average organoleptic values for whole eviscerated chickens irradiated with fuel elements and stored for 1 day at four temperatures

Irradiation dose (rep)	Temperature	Dark				White			
		Flavor	Color	Texture	Odor	Flavor	Color	Texture	Odor
	°F.								
0	0	8.4	8.8	8.7	8.7	8.4	8.8	7.8	8.8
0	34	8.3	8.7	8.9	8.3	8.3	9.0	8.6	8.9
0	40	8.8	8.4	8.5	8.8	8.7	8.8	8.7	9.0
0	58	8.8	8.8	8.5	8.8	8.8	8.9	8.0	8.8
(average)		8.6	8.7	8.6	8.6	8.6	8.9	8.3	8.9
1×10^5	0	8.0	8.4	8.7	8.0	8.3	8.1	7.9	8.4
1×10^5	34	8.5	8.1	8.7	8.8	8.4	8.7	8.7	8.8
1×10^5	40	8.9	8.9	8.9	8.7	9.0	8.9	8.6	9.0
1×10^5	58	8.7	8.3	8.5	8.8	8.4	8.1	8.1	8.7
(average)		8.5	8.4	8.7	8.6	8.5	8.4	8.3	8.7
5×10^5	0	8.6	9.0	8.7	8.7	8.9	9.0	8.3	8.9
5×10^5	34	8.7	8.6	8.6	8.7	8.4	8.9	8.6	8.6
5×10^5	40	8.1	7.6	8.3	8.6	8.7	8.3	8.3	8.9
5×10^5	58	8.5	8.7	8.7	8.7	8.5	8.9	7.9	8.7
(average)		8.5	8.5	8.6	8.7	8.6	8.8	8.3	8.8

TABLE 3

Total aerobic plate counts for comparison of Cobalt 60 and fuel elements for chicken irradiation

(Means of logs significant at 1% level)

	Swab outside	Swab inside	Tissue
Unstored (2 days)	1.83	2.16	1.93
Stored (7 days)	6.13	5.98	4.83
34° F	2.26	2.57	1.96
40° F	5.70	5.57	4.80
Radiated	3.82	2.92	2.85
Unirradiated	4.94	5.22	3.91
Cobalt 60	3.40		2.73
Fuel elements	4.56		4.03
Average	3.98	4.07	3.38

Cobalt 60 had lower plate counts for swab outside, swab inside, and tissue than those irradiated with fuel elements.

The finding that chickens radiated with Cobalt 60 have significantly lower plate counts than those radiated with fuel elements is contrary to popular belief. As both of these are sources of gamma rays, it has been assumed that the effectiveness per unit of dosage would be the same. Perhaps the apparent superiority of Cobalt 60 may be ascribed to the difference in wave length of radiation. It is known that Cobalt 60 emits radiant energy at fixed wave lengths whereas fuel elements contain a heterogeneous mixture of radioactive materials which emit gamma rays at different wave lengths. Thus, the wave lengths of rays emitted by a given fuel rod source would depend upon the initial composition and age of the rods.

It may be that the application of these sources to foods with a microbiological flora different from chickens would show fuel elements to be as effective or even superior to Cobalt 60. However, these results serve to emphasize the fact that dosages may have to be adjusted in changing from one source to another.

2. *Organoleptic Evaluation.* In statistically analyzing the organoleptic data the following independent variables were included in the model: storage period—unstored (2 days) vs. stored (7 days); radiation—unirradiated vs. radiated; source—Cobalt 60 vs. fuel elements; storage period x radiation; storage period x source and three replications. Only the 99% confidence level was considered significant.

Both dark meat and white meat from each sample were tested as outlined in Material and Methods. Storage time was the only factor that caused a significant difference in organoleptic ratings. The color of the dark meat and the texture of the white meat were the only factors that were not significantly affected by storage. Table 4 shows the average values of those quality characteristics that were significantly affected by storage. Results confirm the observations in the first two studies that the panel could not distinguish between radiated and unirradiated samples. They also show that either Cobalt 60 or fuel elements can be used in the radiation pasteurization of fresh chickens without changing the quality characteristics.

TABLE 4

Average organoleptic values for stored and unstored samples of irradiated chicken

(Values significant at the 1% level)

	Dark meat			White meat		
	Flavor	Texture	Off-flavor	Flavor	Color	Off-flavor
Unstored (2 days)	8.63	8.80	8.74	8.72	8.97	8.80
Stored (7 days)	8.13	8.62	8.14	8.30	8.81	8.41
Average	8.38	8.71	8.44	8.51	8.89	8.61

SUMMARY

The effectiveness of pasteurization doses of gamma rays on microbiological and organoleptic quality of whole eviscerated chickens subsequently stored at refrigerated temperatures was investigated. Two gamma ray sources, Cobalt 60 and fuel elements, were used in this study. The following observations were made:

a. At the higher storage temperatures the rate of bacterial multiplication, for both the radiated and unirradiated chickens, was more rapid than at the lower storage temperatures.

b. Unirradiated chickens showed higher TPC than those radiated. This resulted in radiated chickens having a longer microbiological storage life than unirradiated chickens.

c. Cobalt 60 showed a significant advantage over fuel elements in destroying bacteria or in establishing conditions that reduce bacterial multiplication.

d. The rate of rancidity development appeared to be proportional to the radiation dose and inversely proportional to the storage temperature.

e. The taste panel was unable to distinguish between radiated and unirradiated samples of chicken meat when dosage levels of 1×10^5 and 5×10^5 rep were used.

Acknowledgments

The authors wish to express their appreciation to Dr. H. W. Norton, University of Illinois, for aid in the statistical analysis of data and to the personnel of the Michigan Memorial Phoenix Project, University of Michigan, Ann Arbor, Michigan, for direction and aid in the use of the irradiation facilities.

We also wish to acknowledge The Refrigeration Research Foundation, Colorado Springs, Colorado for their financial aid.

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Notes and Letters

Editor, *Food Technology*
Chicago, Ill.

Dear Sir:

The recent note in *Food Technology*, "Locating Russian Materials on Food & Food Technology," quite pointedly indicated the lack of available Russian literature in this country. However, the United States does not hold a monopoly on "ignorance" of activities in the Soviet science and technology.

The following excerpt from the Intelligence and Information Division of the Department of Scientific and Industrial Research-Report for the year 1955–1956, page 70, Her Majesty's Stationery Office, London, points up the similar condition in the United Kingdom.

"It appears that about 1,000 Soviet periodicals are now being abstracted by the Institute of Scientific Information of the U.S.S.R. Academy of Sciences. The Russian abstract publications are fully available in this country (U.K.) and a detailed sample analysis is being made to examine the significance of Russian work in different fields. From this analysis it is hoped to decide what type of translation service is necessary. This survey has so far revealed that only 370 different current Russian scientific and technical periodicals can be found in the country anywhere, and that only a small percentage of the Russian output of scientific and technical books is available. Using information supplied by over 170 of the larger libraries regarding their holdings, a check was made of a particular sample of Russian abstracts of Russian material; this revealed that only 41% of the originals of the items abstracted could be located in this country. To remedy this situation it is proposed to create a Russian Literature Center as the first installment of the National Science Lending Library."

It should also be borne in mind that wholesale acquisition and translation of Russian literature would probably be wasteful and non-productive. The growing "feeling" that all things Russian are to be praised and cherished, is overdoing it a bit.

Very truly yours,

Melvin A. Benarde, Ph.D.
Assistant Professor,
Department of Zoology
University of Maryland

November 18, 1958

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This new member of Givaudan's flavor family exactly reproduces the mouth-watering goodness of rich, ripe peaches. All the delicate nuances of aroma and flavor are captured and concentrated for use in your ice creams, sherbets, candy, pie fillings and pharmaceutical products. Our peach flavor is also recommended as a modifying note for orange or cherry beverages, and is available in powdered or liquid form. To achieve the full natural flavor of fresh peach in your product, try Givaudan's Imitation Peach. Write for samples and full information.

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problems of the company. A commercial company looks upon research as "anticipation of future profit from research." The objectives of commercial food research are: (1) Consumer protection, (2) Consumer satisfaction, (3) Product franchise protection, and (4) New product business. A modern consumer demands: (1) Palatability, (2) Convenience (more and more each year), (3) Economy, and (4) Nutrition.

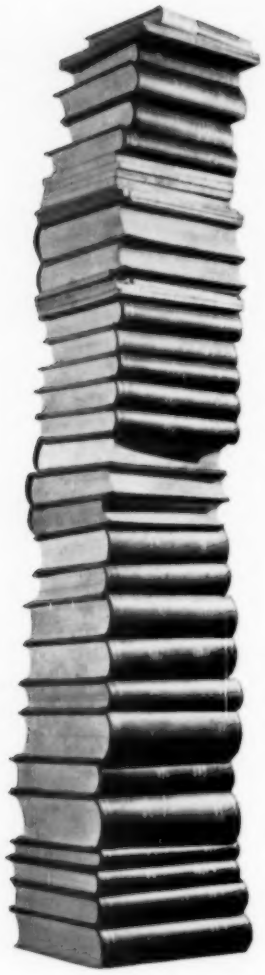
One hundred million dollars is spent each year for research and development by 20,000 scientists. General Foods has a "PODCC" of research—"Planning, Organizing, Directing, Coordinating, and Consulting." One bit of advice offered by Dr. Olsen was to be sure to include the cost and time needed to write a report of the research when planning a project. Don't spread your efforts too thin by trying to do too much, cut your program to fit the personnel, time, etc. of your organization. Dr. Olsen's pet word is "serendipity"—meaning unexpected dividends—and he emphasized that research successes are not always attained by reaching the goals originally set. Unexpected dividends come from unexpected by-products of investigative work on occasion.

Food Technology had its beginnings in the "hustle and bustle" period of the 1890's—"the men hustled and the ladies wore the bustles." The Ford automobile came into being about 1896 right along with Food Technology. Shredded wheat came out in 1893, Grape Nuts in 1895. Jello, the first dessert mix, was also invented in 1895. Aunt Jemima Pancake Mix—the forerunner of today's cake mixes—and Swan's Down Cake Flour began in the 1890's.

Plastics represent the basic science approach to Food Technology and prepared cereals represent the empirical method.

Today the IFT has an annual budget well over $100,000 and a goal of 6,000 members by the meeting in Philadelphia in May 1959. —*Cordelia Ellis*

WINS FOOD TECHNOLOGY SCHOLARSHIP—Gordon H. Wells Jr. (left) of Albion, N. Y., is shown receiving a $1,000 Gerber Scholarship for work in food technology at the University of Georgia. Making the presentation, at a dinner meeting of the Dixie Section of the Institute of Food Technologists on the Georgia campus, was Ray B. Wakefield (right), director of research for the Gerber Products Company and president-elect of the Institute. In the center is Dr. John J. Powers, head of the University of Georgia Food Technology Department. One of the six buildings now under construction in Georgia's $12,500,000 Science Center will be devoted to food technology. The scholarship given to Wells was one of six in a national contest.



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Introduction

As part of a continuing study of the properties of distilled monoglycerides, it is of interest to know the solubility of water and water solutions in mixtures of oil and distilled monoglycerides.

This phenomenon has several interesting applications. It has been suggested, for example, that water-soluble dyes can be used to replace certain oil-soluble F.D.& C. colors by dissolving water solutions of the dyes in oil.

So . . . we tried it, and it works.

Conclusions

1. Fats and oils can be colored, using water-soluble dyes and a monoglyceride as a solubilizing agent.
2. Emulsions can be prepared from these oils and water which have an appearance quite similar to that obtained using oil-soluble dyes.
3. The amount of coloration obtainable by this technique is within a practical range.

We've been trying other things too—the solubilization of various inorganic ionic salts in oil, the dissolving of ascorbic acid, riboflavin, nicotinic acid, caffeine, quinine hydrochloride, and other such physiologically active materials. And we plan to try the solubilization in oils of such materials as sodium cyclamate, monosodium glutamate, amino acids, complexing agents, fungicides, and flavoring agents.

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Literature

BOOKS

LITERATURE ON FOOD RESEARCH AND TECHNOLOGY [1]

Commodities

Fattening steers on small grain pastures. W. C. McCormick, O. M. Hale, and B. L. Southwell. Athens, Ga., 1958. 25 p. (Georgia Agricultural Experiment Station, Bulletin, n.s. 49.) pap. apply.

New research on animal fats and proteins. O. H. M. Wilder. Chicago, 1958. 13 p. (American Meat Institute Foundation, Circular no. 42.) pap. apply.

Quality studies with raw and canned whole kernel sweet corn. N. W. Desrosier, and others. West Lafayette, Ind., 1958. 15 p. (Indiana Agricultural Experiment Station, Research bulletin 655.) pap. apply.

Quality yield relationships of sweet corn for processing. N. W. Desrosier, K. R. Johnson and S. R. Miles. West Lafayette, Ind., 1958. 15 p. (Indiana Agricultural Experiment Station, Research bulletin 654.) pap. apply.

Studies on beef quality. VII. The influence of certain holding conditions on weight losses and eating quality of fresh and frozen beef carcasses. P. E. Bouton, A. Howard, and R. A. Lawrie. Melbourne, 1958. 31 p. (Australia, Commonwealth Scientific and Research Organization, Division of Food Preservation, Technical paper, no. 8.)

FOOD TECHNOLOGY

Dehydration of milk. Phase I. Origin of off-flavors which occur in dry milk during storage. Final report. S. Patton. Chicago Quartermaster Food and Container Institute, 1957. 8 p. processed. Report of contract work done at the Department of Dairy Science, Pennsylvania State University. Order of Library of Congress mentioning PB 133032. Microfilm $1.80. Photoprint $1.80.

Judging quality of tomatoes for processing by objective color-evaluation. John N. Yeatman and Arthur P. Sidwell. Washington, U. S. Govt. Print. Off., 1958. 51 p. (U. S. Dept. of Agr. Marketing research report no. 235.) pap. $0.35.

Vegetable dehydration practice. London, Ministry of Agriculture, Fisheries and Food, 1958. 48 p. processed. Records experiences since the 1948 monograph "Vegetable Dehydration."

Chemical and Biological Aspects

Annual review of microbiology, v. 12. Charles Egolf Clifton and others, ed. Palo Alto, Cal., Annual Reviews Inc., 1958. 588 p. $7.00.

Food and You. E. S. Nasset. New York, Barnes and Noble, 1958. 166 pp. $1.25.

Metals and enzyme activity. Eric Mitchell Cook, ed. New York, Cambridge University Press, 1958. 102 pp. (Biochemical Society symposium no. 15.) $3.75. Symposium held at the University of Leeds, July 13, 1956.

Theoretical principles of organic chemistry, v. 2. Walter Hückel. Translated from the 7th corr. German ed. by F. H. Rathmann. Princeton, N. J., D. Van Nostrand, 1958. 1057 p. $19.00. A critical analysis of both historical and modern theories in organic chemistry.

Economic and Social Aspects

Agricultural statistics, 1957. U. S. Department of Agriculture. Washington, U. S. Govt. Print. Off., 1958. 752 p. $2.00. Includes a revision of per capita consumption data for food items.

Marketing hogs; seasonal patterns in numbers and prices. P. J. Luby and C. B. Cox. West Lafayette, Ind., 1958. 12 p. (Indiana Agricultural Experiment Station, Research bulletin 657.)

Marketing of Indiana canned tomatoes and tomato products. V. W. Ruttan and J. F. Ritchey. West Lafayette, Ind., 1958. 52 p. (Indiana Agricultural Experiment Station, Mimeo ID-24.)

New developments in the frozen food industry; a study of capital requirements. Washington, 1958. 24 p. (U. S. Dept. of Agri. Marketing research report 236.) pap. apply.

Operating results of food chains in 1957. Wilbur B. England. Boston (63), 1958. var. p. (Harvard University Graduate School of Business Administration, Bureau of Research, Bulletin 154.) pap. $2.00.

Food Preference

Consumer preferences, usages, and buying practices for poultry and poultry products. Margaret Weidenhamer. Washington, U. S. Govt. Print. Off., 1958. 136 p. (U. S. Dept. of Agr. Marketing research report no. 252.) pap. $0.65.

Miscellaneous

Home baking by households in the United States—by region. Washington, U. S. Govt. Print. Off., 1958. 130 p. (U. S. Dept. of Agr., Household food consumption survey 1955, Report no. 13.) pap. $0.75.

Information for scientists; a national program for increasing the availability of the results of scientific research. Washington, National Science Foundation, 1958. 11 p. pap. apply. Why and what of a program in which food technologists have an interest.

List of current serials received in the library of the United States Department of Agriculture as of July 1, 1957. Elizabeth G. Davis, comp. Washington, U. S. Govt. Print. Off., 1958. 614 p. (U. S. Dept. of Agr. Miscellaneous publication 765.) pap. $2.25. A useful check list which includes titles on food and food technology.

What's available in the unclassified atomic energy literature. Oak Ridge, Tenn., 1958. 64 p. (U. S. Atomic Energy Commission, Technical Information Service Extension. TID-4450, 5th rev.) A manual on how to find and use AEC reports of use to food technologists interested in radiation.

Russian Literature

[*Beet sugar technology and white sugar refining.*] Teknologiia sveklosakharnago i refinadnogo proizvodstva. P. M. Silin. Moscow, Pishchepromizdat, 1958. 600 p.

[*Butchering and processing poultry.*] Uboi obrabotka ptitsy. I. A. Bakhitin. Moscow, Pishchepromizdat, 1958. 40 p.

[*Meat products; a handbook.*] Miasnya tovary; spravochnoe posobie. M. A. Gabriel'iants and V. A. Petrov. Moscow, Gos. izd-vo torg lit-ry, 1958. 273 p. (Bibliotheka prodavtsai.)

[*Microbiological control in meat plants.*] Mikrobiologichskii kontrol' na miasokombinatakh. L. I. Bogdanova. Moscow, Pishchepronizdat, 1958. 137 p.

[*Science of food supplies, introduction, cereals and flour, fruits and vegetables, confectionery and spices,* v. 1.] Tovarovednie prodovol'stvennykh tovarov, vvednie, tovary zerno-nuchnye, plodoovskehnye, konditerske, vkusovye, v. 1. Pd. red. V. G. Sperankago. G. S. Inikhov and others. Moscow, Gos. izd-vo torg. lit-ry, 1958. 502 p.

[*Technology and chemical control of sugar beet manufacture.*] Tekhnologiia i teknokhimicheskii kontrol' sveklosakharnogo proizvodstva. B. P. Shumkov, and S. I. Korol'kov. Moscow, Pis-chchepronizdat, 1957. 399 p.

[1] Material for this list should be sent to Dr. James G. Hodgson, Chief, Library Branch, Quartermaster Food and Container Institute for the Armed Forces, 1819 W. Pershing Road. Chicago 9, Illinois.

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ABSTRACTS

—Compiled by H. A. Campbell

ANALYTICAL METHODS

Shape of spot and rate of sorption in paper chromatography.

KAUMAN, S. H. AND BAK, T. A. (Fac. of Sci., Univ. of Brussels, Belgium). *Nature 182*, 743–4 (1958).

The theory presented provides not only a value for the rate of advancement of the spot but also gives an explanation for its shape. Furthermore, by comparing the 2 axes of the elliptical spot at different velocities, it is possible to deduce the values of rate constants for adsorption and desorption.

BIOLOGICAL SCIENCES

Biochemistry

N-terminal amino acids of the floating fraction of egg yolk.

SMITH, D. B. AND TURNER, K. J. (Div. of Appl. Biol., Natl. Research Council, Ottawa, Can.). *Can. J. Biochem. Physiol. 36*, 951–2 (1958).

Lysine is the major N-terminal amino acid of both the sol. and insol. fractions of the floating lipoprotein of hen's egg yolk, which suggests a common primary structure. Several minor components are also present in both fractions.

Studies on the cold-insoluble fraction of the water-extractable soybean proteins. II. Factors influencing conformation changes in the 11 S component.

WOLF, W. J. AND BRIGGS, D. R. (Dept. of Agr. Biochem., Univ. of Minnesota, St. Paul). *Arch. Biochem. Biophys. 76*, 377–93 (1958).

Ultracentrifugal studies indicate that the 11 *S* globulin of soybeans is capable of undergoing conformation changes probably involving dissocn. into subunits which appear to be ½ and approximately ⅛ the size of the 11 *S* molecule. These changes occur at low ionic strength at alk. pH values, at moderate ionic strengths at acid pH values, in the presence of sodium octylbenzenesulfonate and in the presence of relatively low concns. of urea.

Principles of protein structure and their application to synthetic polypeptides and fibrous proteins.

HUGGINS, M. L. (Eastman Kodak Co., Rochester, N. Y.) *J. Polymer Sci. 30*, 5–10 (1958).

The principles of protein structure are stated and their application is illustrated by brief consideration of the structures of silk, polyglycine II, α- and β-polypeptides, α- and β-keratin and collagen.

The decomposition of keratin by microorganisms.

NOVAL, J. J. (Rutgers Univ., New Brunswick, N. J.). *Dissertation Abstr. 19*, 219–20 (1958).

Keratin (wool and feather), sterilized by vapors of ethylene oxide, or by chloroform, can be digested by growing cultures of *Streptomyces fradiae*. Cell free broths obtained from cultures of *S. fradiae* digested keratins and casein rapidly. The mechanism is apparently similar to that proposed for the digestion of wool by insects; that is, by the combined attack of reducing and proteolytic agents.

Epinephrine and carbohydrate metabolism.

DRURY, D. R. AND WICK, A. N. (School of Med., Univ. of Southern California, Los Angeles). *Am. J. Physiol. 194*, 465–8 (1958).

It is generally accepted that epinephrine promotes the breakdown of muscle glycogen to lactic caid and that this lactic acid is largely reconverted to glycogen by the liver. The authors have reexamined this concept making use of lactate, and glucose, C^{14}-labelled. They found that the lactate is very quickly oxidized to CO_2 and very little is converted to glucose or glycogen. The lactate is much more quickly burned than is the glucose. The lactate set free by epinephrine serves as an important emergency fuel that can be quickly burned by the organism.

Microbiology

Essential amino acids in microbial proteins.

ANDERSON, R. F. AND JACKSON, R. W. (Northern Utilization Research and Devel. Div., Peoria, Ill.). *Appl. Microbiol. 6*, 369–73 (1958).

This review includes a tabular summary of investigations published during the last 10 years on the amino acid compn. of algae and other microorganisms.

The inhibition in beef of chlortetracycline-resistant bacteria by subbacteriostatic concentrations of the antibiotic.

JAY, J. M., WEISER, H. H. AND DEATHERAGE, F. E. (Dept. of Animal Sci., Ohio State Univ., Columbus). *Appl. Microbiol. 6*, 343–6 (1958).

Whereas low concns. of chlortetracycline are effective in raw beef against certain strains of *Proteus vulgaris* and *Pseudomonas aeruginosa*, the antibiotic was totally ineffective against these same organisms in cooked beef. The antibiotic was still effective in distd. water exts. of beef, but not in saline exts. Heating the exts. for 30 min. at room temps. up to 90° C. did not bring about the loss of the effectiveness of the antibiotic. Heating above 100° C. did bring about a loss of the effectiveness. Previous data suggest that these phenomena are related to the release of nutrient substances to the organisms in the form of anions and cations.

Phenolic compounds in brown algae. I. The presence of reducing compounds in Ascophyllum nodosum (L.) Le Jol.

HAUG, A. AND LARSEN, B. (Norwegian Inst. of Seaweed Research, N.T.H., Trondheim, Norway). *Acta Chem. Scand. 12*, 650–7 (1958).

The brown alga *Ascophyllum nodosum* contains amts. of reducing compds. varying from 0.4 to 2.25 meq/g. dry matter depending on place of growth. Evidence is presented which indicates that the reducing compds. show reactions characteristic of phenols, and that they are identical with the compds. giving the color reaction of the physodes ("fucosan").

Nutrition

Availability to man of amino acids from foods. I. General methods.

LINKSWILER, H., GESCHWENDER, D., ELLISON, J. AND FOX, H. M. (Dept. of Home Econ., College of Agr., Univ. of Nebraska, Lincoln). *J. Nutrition 65*, 441–54 (1958).

The replacement of a portion of the 12 amino acids in purified diets by those in wheat or in corn resulted in a slight improvement in nitrogen balance of human subjects. Since this improvement was slight and of uncertain significance, the results of the present investigation indicate that availability of an amino acid in natural food can be detd. for man by feeding in alternate periods an equiv. amt. of a purified and of a bound amino acid in food. It seems that man is able to use efficiently a combination of bound and of purified amino acids even when all of certain amino acids, are ingested as bound amino acids from corn and when a major portion of others are ingested in purified form.

Availability to man of amino acids from foods. II. Valine from corn.

LINKSWILER, H., FOX, H. M., GESCHWENDER, D. AND FRY, P. C. (Dept. of Home Econ., Coll. of Agr., Univ. of Nebraska, Lincoln). *J. Nutrition 65*, 455–68 (1958).

The availability of valine in corn for human subjects has been detd. by feeding in alternate periods a diet contg. the same amt. of valine in corn. Nitrogen balance performance of the subjects was compared on these 2 diets as the valine intake was decreased from 530 to 230 mg. daily. From the data obtained

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in this expt. it appears that the valine in corn is as well utilized as purified valine.

The effectiveness of essential amino acid supplementation in overcoming the growth depression of unheated soybean meal.

FISHER, H. AND JOHNSON, D. (Dept. of Poultry Sci., Rutgers Univ., New Brunswick, N. J.). *Arch. Biochem. Biophys. 77*, 124–8 (1958).

Methionine supplementation to raw soybean meal and the feeding of increased amts. of raw soybean meal improved the growth performance on raw soybean protein diets in line with previous studies. Supplementation of 15% raw soybean protein with either a mixt. of essential amino acids known to be well balanced or with egg albumin overcame nearly all of the growth-depressing activity of raw meal. Neither the amino acid mixt. nor the egg albumin, as the only source of dietary nitrogen, supported the excellent growth obtained in combination with raw soybean meal. It is concluded that amino acid availability is a major factor in the growth-depressing activity of raw soybean meal.

Niacin-tryptophan requirements of man.

HORWITT, M. K. (Dept. of Biol. Chem., Univ. of Illinois, College of Med., Elgin). *J. Am. Dietetic Assoc. 34*, 914–19 (1958).

The value of 60 mg. tryptophan has been selected as the equiv. of 1 mg. of niacin. The niacin tryptophan requirement of man is a function of the energy expended and 8.8 mg. niacin-equiv. seems to be the amt. needed to barely prevent pellagra in individuals consuming 2000 calories or less/day. As a consequence of this 4.4 mg. niacin-equiv./1000 calories is considered a basic allotment to which a 50% safety factor is added giving the min. allowance of 6.6 mg./1000 calories.

The effects of amino acid ingestion on gastric secretion comparison of lysine and arginine.

SACKLER, A. M. AND SOPHIAN, L. H. (Du Pont de Nemours, Inc.). *J. Lab. Clin. Med. 52*, 43–7 (1958).

Arginine monohydrochloride, administered in a dose of 5 g. with a bread and water test meal, produced no significant changes in the amt. of HCl or pepsin detectable. This is in distinction to the effect of lysine monohydrochloride which, given in an identical dose, produced a substantial rise in pepsin and a moderate rise in HCl as measured fractionally.

Dietary protein and serum cholesterol.

NATH, N., HARPER, A. E. AND ELVEHJEM, C. A. (Dept. of Biochem., Univ. of Wisconsin, Madison). *Arch. Biochem. Biophys. 77*, 234–6 (1958).

The effects of casein and wheat gluten on serum cholesterol in the rat were compared. When casein was replaced with increasing amts. of wheat gluten in the diet, a progressive lowering of serum cholesterol levels occurred.

The effect of dietary fat on the fatty acid composition of cholesterol esters in rat liver.

MUKHERJEE, S., ACHAYA, K. T., DUEL, H. J. AND ALFIN-SLATER, R. B. (Univ. of Southern California School of Med., Los Angeles). *J. Nutrition 65*, 469–79 (1958).

The differences in fatty acid compn. of cholesterol esters in the liver of rats have been compared in adult rats fed from weaning on diets contg. different dietary fats. Animals fed a diet contg. 15% of lard, which besides adequate amts. of essential fatty acids, contains larger amts. of satd. fatty acids, tend to accumulate cholesterol in the liver. Increased proportions of cholesterol are esterified with the more satd. fatty acids. Diets contg. highly satd. fats, such as hydrogenated coconut oil, result in the formation of large amts. of satd. fatty acid esters of cholesterol deposited in the liver. In the absence of fat from the diet, there is very little polyunsatd. or essential fatty acid found in the cholesterol esters in the rat liver. It is concluded that the compn. of the dietary fat exerts a marked influence on the fatty acid pattern exhibited by the cholesterol esters in the liver.

The modification of egg-yolk fats by sunflower-seed oil and the effect of such yolk fats on blood-cholesterol levels.

HORLICK, L. AND O'NEIL, J. B. (Dept. of Med., Univ. of Saskatchewan, Saskatoon, Can.). *Lancet 7040*, 243-4 (1958).

Feeding 10% sunflower seed oil (linoleic-acid content about 60%) to hens for an 8 week period showed a sixfold increase in the di-unsatd. C^{18} acids of eggs, which was almost entirely due to linoleic acid. Perhaps modification of foodstuffs, may enable us to achieve the blood-cholesterol levels now seen in populations which have low morbidity and mortality from atherosclerosis.

Influence of magnesium deficiency on serum cholesterol levels in the rat.

KREHL, W. A. AND BARBORIAK, J. J. (Yale Univ. School of Med., New Haven, Conn.). *Am. J. Physiol. 194*, 387–9 (1958).

Magnesium-deficient, high-fat and high-carbohydrate diets contg. 5 mg. Mg/100 g. were fed to weanling albino rats in order to learn more about the possible relationship between Mg and lipid metabolism. After 10 wks. of feeding, the blood cholesterol levels of the fat-fed male rats were significantly higher than those fed the carbohydrate diet. Retardation of growth was more pronounced in the groups fed the high-fat diet.

Plant sterols, degree of unsaturation and hypocholesterolemic action of certain fats.

BEVERIDGE, J. M., CONNELL, W. R., MAYER, G. A. AND HAUST, H. L. (Dept. of Biochem., Fac. of Med., Queens Univ., Kingston, Ontario, Can.). *Can. J. Biochem. Physiol. 36*, 895–911 (1958).

Dietary expts. in which food was supplied in the form of a homogeneous liquid formula ration of definitely known compn. have been performed on 171 subjects (159 men and 12 women). Plasma cholesterol analyses were performed. The results obtained were interpreted as indicating that: firstly, there is no simple relationship between the hypocholesterolemic effect of an oil and degree of unsatn.; secondly, sitosterol or something closely assocd. with this sterol in the unsaponifiable matter accounts for a large part of the hypocholesterolemic activity of corn oil; and thirdly, certain fatty acids of short chain length or some other substance in butterfat and coconut oil have a hypercholesterolemic effect.

Feeding the newborn infant.

Nutrition Revs. 16, 233–4 (1958).

A survey of the feeding practices of infants in hospitals throughout the country has been compiled. The majority of reporting hospitals used only one "house formula" and this consisted of various modifications of evaporated milk in 65.8%, premodified prepd. formulas in 30.9%, pasteurized milk in 3.1% and pasteurized skim milk in 0.2%.

Thiamine deficiency in infants.

Nutrition Revs. 16, 240–1 (1958).

The continued appearance of instances of vitamin deficiency in the literature would suggest that, at the present time, the most clear-cut examples of nutritional deficiency of infants in this country occur in allergic children whose diets have been modified extensively during the course of their treatment.

Effect of partial replacement of rice in the diet by enriched wheat macaroni on the general health and nutritional status of children.

SUBRAHMANYAN, V., BHAGAVAN, R. K., *et al.* (Central Food Technol. Research Inst., Myosore). *Food Sci.* (India) 7, 143–6 (1958).

A 6-month feeding study indicated that children receiving wheat macaroni contg. low fat groundnut flour, B-vitamins and Ca showed a significant improvement in wt. and hemoglobin over those in a control group.

Tobacco amblyopea: a clinical manifestation of vitamin-B_{12} deficiency.

HEATON, J. M., MCCORMICK, A. J. AND FREEMAN, A. G. (Univ. of Bristol, Engl.). *Lancet 7041*, 287–90 (1958).

Evidence is presented that, in persons with even mild vitamin-B_{12} deficiency the retina or the optic nerve is unduly sensitive to tobacco. In a limited clinical trial the effect of parenteral cyanocoalamin in improving visual acuity and completely reversing changes in the visual field was most encouraging, even if use of tobacco continued.

Physiology

The effect of human growth hormone in man.

IKKOS, D., LUFT, R. AND GEMZELL, C. A. (Dept. of Endocrinol., Serafimerlaserettet, Stockholm, Sweden). *Lancet 7023*, 720–1 (1958).

Growth hormone purified from human pituitaries had a pronounced metabolic effect in 2 human subjects. A daily dose of 10 mg. produced retention of nitrogen, phosphorus, and potassium; retention of sodium and chloride; and increase in the urinary excretion of calcium. In one of the subjects the excretion of acetone in the urine increased greatly and the creatine excretion, which was abnormally high, fell to normal during the hormone administration.

Toxicology

Effect of a laminarin sulfate (LM 46) on bone growth.

ADAMS, S. S., THORPE, H. M. AND GLYNN, L. E. (Boots Pure Drug Co., Nottingham, Engl.). *Lancet 7047*, 618–19 (1958).

Laminarin is a polysaccharide consisting of approximately 20–30 glucose units joined by β-1:3 linkages, and occasionally a β-1:6 linkage. One of these compds.—LM 46—was more toxic and more highly sulfated than the others. In all animals there was a pronounced loss of weight after prolonged dosing, and they seemed very frail both in appearance and when handled. The rabbits and guinea pigs had a white discharge in the eyes. The most interesting effects, however, were the skeletal abnormalities, which were most striking in rabbits. There is some evidence that the effect of this laminarin sulfate may be shared by other sulfated polysaccharides.

ENGINEERING RESEARCH

Continuous pulping of wood chips.

LUNDBERG, L. A. *Chem. Eng. Progr. 53*, 497–500 (1957).

A brief description of some of the equipment used in the continuous pulping of wood chips, including a discussion of their advantages and disadvantages as compared to batch pulpers.

FOOD AND FOOD TECHNOLOGY

Baking and Bakery Products

The effect of sucrose on gluten development and the solubility of the proteins of a soft wheat flour.

BACTER, E. J. AND HESTER, E. E. (Pillsbury Mills, Inc., Louisville, Kentucky). *Cereal Chem. 35*, 366–74 (1958).

Additions of 15 and 30% sucrose (flour basis) to soft wheat flour increased dough development time in the mixograph. Sucrose levels of 60 and 120% prevented dough formation; this was attributed to the competition between sucrose and the gluten proteins for water. The percentage of sol. protein extractable from gluten dispersions in water and sucrose solns. decreased with an increase in the protein concn. in the medium and increased with increases in sucrose concn. Peptization was greater at 25° C. than at 100° C.

Preparation of 3-stearoyl-D-glucose — a bread-softening agent.

OTEY, F. H. AND MEHLTRETTER, C. L. (Northern Utilization Research and Devel. Div., Peoria, Ill.). *J. Am. Oil Chemists' Soc. 35*, 455–7 (1958).

In previous work 3-stearoyl-D-glucose was found to have superior bread softening action. This paper describes its synthesis by reaction of stearoyl chloride with 1, 2:5, 6-di*iso*propylidene-D-glucose. Acetonation of the product, followed by saponification of the acyl group, produced 1, 2:5, 6-di*iso*propylidene-D-glucose and indicated that the substance is 3-stearoyl-D-glucose.

Cereals and Grains

Investigation of the behavior of wheat during drying.

DIETRICH, N. *Chem.-Ing. Tech. 30*, 511–13 (1958).

Since mature, naturally damp grain is only available for a few days in the year for purposes of drying expts., in most of the earlier expts. use was made of artificially moistened wheat. The different nature of the moisture take-up in naturally damp and artificially moistened wheat made it appear desirable to find an answer to the question of whether results obtained in drying expts. using moistened grain are also valid for naturally damp wheat. The difference between the drying times for naturally damp and artificially moistened wheat increases the higher the initial moisture and the lower the dry air temp.

Coffee

Nutritional study of instant coffee powder.

TEPLY, L. J. (Wisconsin Alumni Research Foundation, Madison). *Food Technol. 12*, 485–6 (1958).

The presence of an average of 0.33 mg. niacin/g. of instant coffee powder was confirmed by bioassay. Regular instant coffee powder contained from 0.22 to 0.53 mg. niacin/g. Two samples of decaffeinated instant coffee powder contained 0.37 and 0.41 mg. niacin/g. Measurable, but low, levels of 8 other B vitamins and of Na, Ca, Fe and Fl were found in instant coffee powder.

Gums

Water-soluble gums of improved water solubility.

HENRY, J. E. Assignor to Hercules Powder Co. U. S. 2,807,591. Sept. 24, 1957.

A novel method of improving cold water dispersibility of a hydrophilic gum which otherwise tends to clump is described. The gum is admixed in the dry state with a water sol. mixt. which evolves sufficient CO_2 upon addn. to H_2O to disperse the gum and reduce the tendency to form agglomerates. Mixtures producing CO_2 suitably are $NaHCO_3$, NaH_2PO_4, or citric acid. Thus, typically, sodium carboxymethyl-cellulose required 18.6 min. to dissolve under a given set of conditions. However, by previously admixing it with 32%, Na_2CO_3 and 18% $NaHSO_3$, the soln. rate was less than 30 sec., using the same conditions.

Legislation

Articles on food and drug law.

CHRISTOPHER, T. W. (Emory Univ., Atlanta, Georgia). *Food Drug Cosmetic Law J. 13*, 487–98 (1958).

A comprehensive list of writings in legal periodicals on the subject of food and drug laws has been compiled by the author.

Label declaration of D-erythroascorbic acid when it is an ingredient of a fabricated food.

ANON. *Federal Register 23*, 5873 (Aug. 2, 1958).

A resolution has been approved to discontinue the use of the name D-*iso*ascor-

bic acid (D-araboascorbic acid, D-erythro-3-ketohexonic acid lactone) and to adopt the name, erythorbic acid, in order to prevent purchasers from associating the former term with the common name of vitamin C. Ascorbic acid (vitamin C) is capable of preventing the deficiency disease, scurvy, but D-*iso*ascorbic acid is ineffective for this purpose.

Meat and Fish

Production and identification of a green pigment formed during irradiation of meat extracts.

FOX, J. B., STREHLER, T., BERNOFSKY, C. AND SCHWEIGERT, B. S. (Am. Meat Inst. Foundation, Chicago, Ill.). *J. Sci. Food Agr. 6*, 692–6 (1958).

Studies of the conditions under which the maximal discoloration of heme pigments occurs, by ionizing radiations, show a maximal relative production of green pigment with respect to red at pH 5.3. This production could be greatly enhanced by the addn. of cysteine or other sulfhydryl reagents and inhibited by the addn. of aldehydes. This evidence, plus the reactions it undergoes with dithionite and CO identifies the green heme pigment as sulfmyoglobin. Evidence is presented that the sulfmyoglobin complex breaks down under either mild oxidizing or reducing conditions to form metmyoglobin or myoglobin. The protein moiety of the green pigment is partially denatured, and the production of the green pigment is postulated to be one of the steps in the irradiation destruction of muscle color.

Milk and Milk Products

Flavor research on cheese.

JACKSON, H. W. (Research and Devel. Div., Natl. Dairy Products Corp., Glenview, Ill.). *Perfumery Essent. Oil Rec. 49*, 256–8 (1958).

The question of the origin and compn. of cheddar cheese flavor is discussed as well as methods of isolation of the volatile components of cheese flavor.

Reconstituted milk product.

MCCARTHY, J. L. U. S. 2,851,358. (Sept. 9, 1958).

When an edible light bloom gelatin sized in the range of 100 bloom is added to a dry milk powder, the reconstituted milk has an improved flavor and texture and is free of a chalky and scorched taste.

Potatoes

Determination of end point in extraction of free amino acids from potatoes.

TALLEY, E. A., CARTER, F. L. AND PORTER, W. L. (Eastern Utilization Research and Devel. Div., U. S. Dept. of Agr., Philadelphia, Penna.). *J. Agr. Food Chem. 6*, 608–10 (1958).

A satisfactory batchwise procedure for the extn. of the free amino acids from potatoes has been developed. Lysine and arginine are the last of the amino acids to be extd. by 70% aq. ethyl alc. using this procedure. The order of extn. of the amino acids in potatoes was very different from that reported in young corn shoots. The author ,states that methods used for the extn. of plant constituents should be tested on each plant material for which they are to be used.

Starch

Separation of carbohydrates on cocoanut charcoal columns.

BARTH, F. W. AND TIMELL, T. E. (McGill Univ., Montreal, Can.). *Can. J. Chem. 36*, 1321–2 (1958).

It was found that cocoanut charcoal, 50–200 mesh, pre-treated with 6 *N* HCl, water, anhyd. EtOH, and again water, was an excellent material for separating both uronic acids and methylated monosaccharides. The rate of flow, even through long columns, was very rapid. The fractions obtained were pure and the sepns. were sharp. The sepn. of a mixt. of uronic acids obtained from the partial hydrolysis of milkweed floss is described.

High amylose corn.

ANON. *J. Agr. Food Chem. 6*, 641–2 (Sept. 1958).

Among new crops developed for industrial uses is high amylose corn. Corn contg. as high as 82% amylose content has been achieved, compared to usual amylose content of 25%. Patented uses for linear amylose are: film making for packaging, for sausage casings, as soluble films, paper making, textiles, molded plastics and detergent adjuncts.

Taste Testing

Nature of taste stimulation by sugar.

HAGSTROM, E. C. AND BROWN, H. *Dissertation Abstr. 18*, 676 (1958).

The results obtained indicate that the selective property of the taste cell is not due to an enzymatic process, but rather to some phys. property of the cell surface. It is concluded that the mechanism of sugar stimulation is not fundamentally different from that for salt stimulation.

The physicochemical aspects of the sense of taste.

FERGUSON, L. N. AND LAWRENCE, A. R. (Howard Univ., Washington, D. C.). *J. Chem. Educ. 35*, 436–43 (1958).

The anatomy and physiology of the taste organs are described and an attempt is made to correlate the tastes of chem. substances with their molecular structures.

Body size and sweetness preference.

PANGBORN, R. M. AND SIMONE, M. (Dept. of Food Technol., Univ. of California, Davis). *J. Am. Dietetic Assoc. 34*, 924–8 (1958).

Apricots, pears, peaches and vanilla ice cream, differing in sugar content, were evaluated during 4 consumer surveys, by a total of 12,505 people. Each consumer's age sex, height, and weight were used to classify him into one of 3 groups, underweight, normal weight, or overweight. No significant correlation was made between sweetness preference and overweight. Overweight consumers tended to rate all food samples higher than did less heavy tasters, suggesting that the liking for food in general, rather than sweet food in particular, is an influencing factor in wt. control.

Miscellaneous

Family buying-decisions: who makes them, who influences them?

Printers' Ink 264, 21–9 (Sept. 19, 1958).

Household decision making was reported, studied and discussed at the fourth conference on Consumer Behavior at the University of Michigan. The conference featured reports of research projects that probe deeply into the factors which influence purchasing choices,—the values, motives, pressures, needs of the modern family—in order to provide better predictors of consumer purchases. Excerpts of these reports are presented.

Industry Publications

Ungerer & Co. Issues New Products Reference List. Mr. F. H. Ungerer, Chairman of the Board, announces publication of a new reference list covering products sold by Ungerer & Co. Inc., 161 Ave. of the Americas, New York 13, N. Y. This catalogue, completely different from previous lists, features a new cover design, showing UNGERER's seal. This seal will also appear on container closures to insure against tampering with products as shipped from Ungerer's Totowa plant or New York stocks. In addition to a complete line of high quality essential oils and aromatic chemicals, this list features UNGERER-VIDAL CHARVET, France, perfume specialties and a wide range of flavors with usage tables to help the customers to determine the product best suited for their needs. Ungerer will be glad to mail a copy on request.

EXPANSION NEWS

New, bright, shiny and clean—and definitely in line with the spirit of modern food manufacture in America is the Home Juice Company Plant, Melrose Park, Illinois. This new building houses an ultramodern fruit juice processing plant and product-handling facilities. Here, too, are the company's executive and business offices, also most modern in concept and functional attractiveness. The company employs 250 persons. Offices and plant occupy 33,000 sq. ft. of space in one corner of a 100,000-sq. ft. site. The structure makes use of both conventional and modern materials to achieve a striking, clean-lined elevation on all sides.

Executives of Home Juice Co. are, left to right: Stephen Poulsen, General Operations Manager; Leonard Poulsen, Chicago Sales Manager; G. C. "Bill" Finneran, Executive Vice President and General Sales Manager and Leonard Haddad, President.

EQUIPMENT

MEAT PORTION COST CALCULATOR OFFERED

A meat portion cost calculator which quickly translates cost per pound into cost per serving is being made available to restaurants, hotels, clubs, hospitals, schools, transportation lines, inplant cafeterias and other feeding establishments by Pfaelzer Brothers, Inc., Chicago, institutional meat purveyors.

The calculator accurately determines the cost of servings from 3 to 24 ounces based on a graduated cost per pound scale.

A guide to menu pricing is also included with the calculator. This guide enables the user to determine proper menu selling price by charting the total meal cost and multiplying by the desired cost percentage.

The cost calculator-meat pricing guide can be obtained free upon request from Dept. CC, Pfaelzer Brothers, Inc., Union Stock Yards, Chicago 9, Illinois.

COMMENT

NEW FILM EXPOSES NUTRITIONAL QUACKERY AND FOOD FADS

The Committee on Nutrition Information of the Food and Nutrition Section of the American Public Health Association recommends to the attention of all who are interested in combatting food fads and nutritional quackery the new film entitled "The Medicine Man" which has been prepared by The American Medical Association in cooperation with the Food and Drug Administration and the National Better Business Bureau. "The Medicine Man" represents a valuable and timely contribution to a concerted educational program to alert the public to the dangers of substituting food fads for sound nutrition.

Designed for use initially in local television programs, the twenty-seven-minute, black-and-white sound motion picture, exposes the dangers created by itinerant health lecturers who give misinformation on nutrition and by food supplement peddlers who misrepresent the value of their nutritional products. How the medical profession, Food and Drug Administration and voluntary agencies such as the National Better Business Bureau cooperate in fighting food quacks is shown, also.

"The Medicine Man" is available through the A.M.A. Communications Division for showing to school, church, club and community audiences.

HORACE L. SIPPLE, *Chairman*
Committee on Nutrition Information
Food and Nutrition Section of the
American Public Health Association

PERSONNEL

Dr. Lloyd A. Hall, Technical Director, The Griffith Laboratories, Inc., will be presented with the Honorary Membership Award of The American Institute of Chemists at a banquet on January 14, 1959 at The Furniture Club, 667 McClurg Court, Chicago. Mayor Richard J. Daley and Mr. F. Willard Griffith, Executive Vice President of The Griffith Laboratories, Inc. will speak concerning Dr. Hall's civic and scientific achievements and Dr. Emil Ott, President of The American Institute of Chemists, will present the Award.

John H. Nair Is Honored with Doctorate from Beloit College

Mr. John H. Nair, long active in IFT affairs, received an honorary Doctor of Science Degree from his Alma Mater, Beloit College, on October 18th at Beloit, Wisconsin, in recognition of his long and significant service to the American Chemical Society. Presentation of the degree was made at the homecoming convocation which climaxed a two-day alumni institute on "Chemistry's Contribution to Mankind's Need for Food."

J. H. Nair

The purpose of this Institute was to focus attention on the problem of the capacity of agriculture to keep pace with human reproductive capacity.

On October 17th, Mr. Nair spoke before the Alumni Institute in Union Ballroom on the subject, "How Adequate Is the World's Food Supply?" Mr. Nair said in part:

"Chemistry is mankind's best hope in feeding a world whose population is expected to double by the end of the century. With more than 100,000 babies born daily, the world's chief concern must be the production of sufficient suitable food to ensure them a reasonable chance to survive and grow. Advances in chemical research must continue to provide new food sources and better use of existing raw materials and processes."

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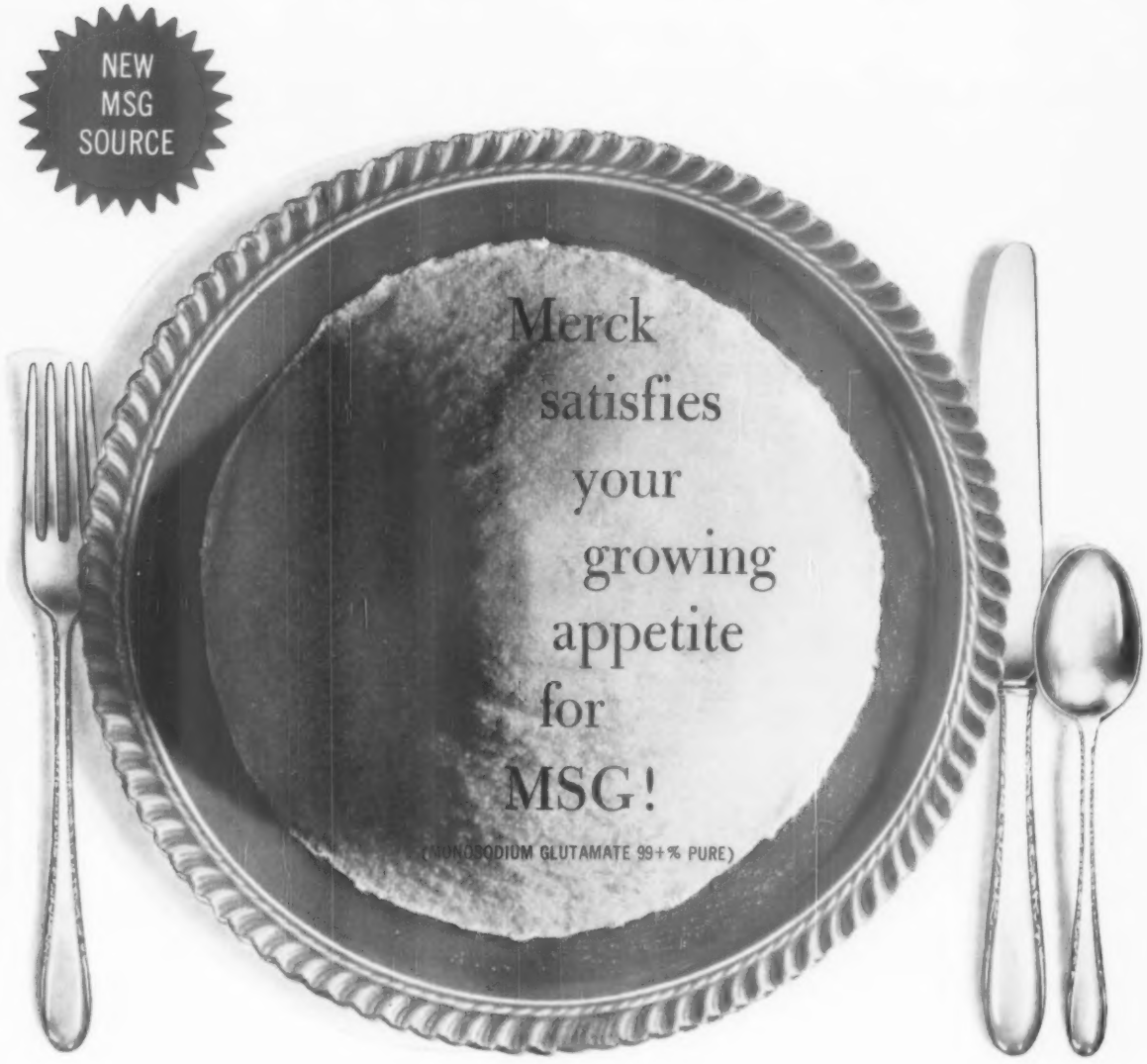
W. J. Considine

Dr. William J. Considine has joined the Felton Chemical Company as Research Director and Head of the Analytical Department. Dr. Considine, a member of IFT, was formerly engaged in organic research with the Sloan Kettering Institute for Cancer Research and the Squibb Institute. Dr. Considine received his Doctorate degree from Yale University and has held teaching positions at both Yale and Columbia Universities.

Colonel John H. Rust, D.V.M., Ph.D., Chief of the Veterinary Pathology Section of the Armed Forces Institute of Pathology retired on December 1 and has become a member of the staff of the Massachusetts Institute of Technology. Dr. Rust is to serve as Project Director of a recently inaugurated research project sponsored by the Atomic Energy Commission relating to new and extended uses for radioisotopes in the food industries which will be conducted at the Massachusetts Institute of Technology. His new duties will necessitate extended travels in the United States previous to making his headquarters in Cambridge, Mass.

A. G. Naik-Kurade

Dr. Anand G. Naik-Kurade has been named Head Food Technologist-cum-Chemist at the Dr. Writer's Chocolates and Canning Co., Bombay, India. Dr. Naik-Kurade received his doctorate from the University of Massachusetts, Amherst, and was a member of the faculty there prior to his appointment to his present post. He is a member of IFT, Phi Tau Sigma, and other professional societies.



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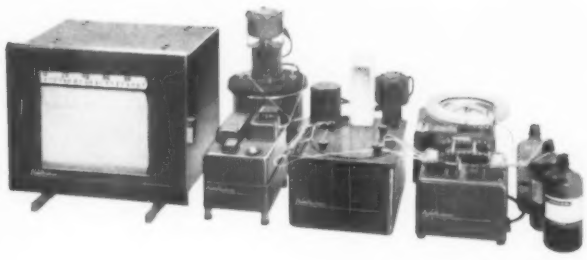

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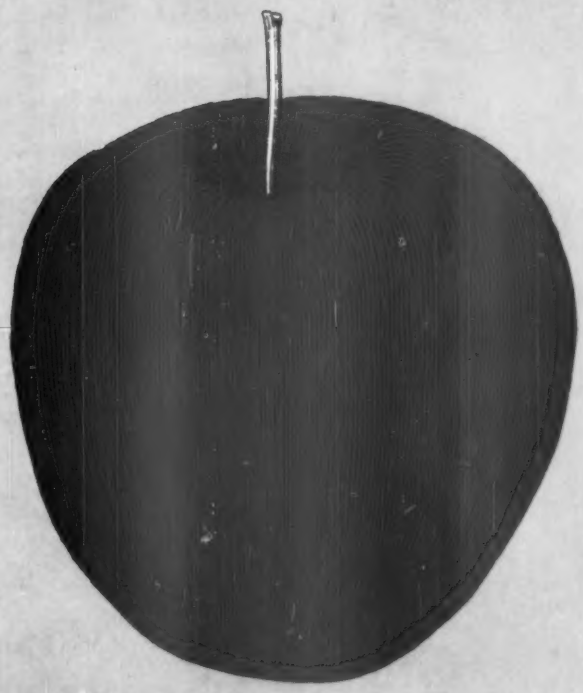

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